EXCESS VOLUMES OF MIXING: THE BENZENE + TRICHLOROETHYLENE SYSTEM

DAVID STEVEN PICKERELL

(2)

EXCESS VOLUMES OF MIXING:
The Benzene + Trichloroethylene System

by

Captain David Steven Pickerell
B.S., United States Military Academy, 1978

A Thesis
Submitted to the Faculty of the
Graduate School of the University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Master of Science

Department of Chemical Engineering
University of Louisville
Louisville, Kentucky

May 1988

SECURITY CLASSIFICATION OF THIS PAGE

ADA197987

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a REPORT SECURITY CLASSIFICATION	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION CPT David S. Pickerell 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION HQDA, MILPERCEN
6c ADDRESS (City, State, and ZIP Code) Student, HQDA, MILPERCEN, ATTN: DAPC-OPA-E 200 Stovall Street Alexandria, VA 22332	7b ADDRESS (City, State, and ZIP Code) ATTN: DAPC-OPA-E 200 Stovall Street Alexandria, VA 22332
8a NAME OF FUNDING/SPONSORING ORGANIZATION HQDA, MILPERCEN 8b OFFICE SYMBOL (If applicable) DAPC-OPA-E	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) 200 Stovall Street Alexandria, VA 22332	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
EXCESS VOLUMES OF MIXING: The Benzene + Trichloroethylene System

12 PERSONAL AUTHOR(S)
Pickerell, David Steven

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final report	FROM May 86 TO May 88	88/05/16	146

16 SUPPLEMENTARY NOTATION

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Excess Volumes, Trichloroethylene, Mixing, Cyclohexane, Benzene

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The excess volume function for the benzene + trichloroethylene (TCE) system was studied at temperatures of 10, 25, 30, and 40 °C in this investigation. Prior to describing this system, benzene + cyclohexane at 25 °C, the test system, was analyzed to determine the ability of the investigator to obtain accurate results with the apparatus and procedures described in this work. The results of the test system were in excellent agreement with those of other experimenters and with the parameters described by Handa and Benson in their summary of the system.

The excess volume function of each system studied was described by a smoothing equation that was derived from an average of 72 data points per system. All of these systems were found to have excess volume curves that were uniformly positive in shape. The benzene + TCE system at all temperatures had maximum values at about 58 percent benzene. This maximum value for the excess volume was related to temperature by the equation $V_{eT} = -.00140 * T + .653697$, where T is in K and V_{eT} is in cc/mol. The data were also
(continued on reverse)

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
CPT David S. Pickerell	(914) 938-3904	

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

checked for consistency, by the data point, by the data set, and by the system at a given temperature, with favorable results. The relationship between temperatures and excess volumes was noted to invert near both ends of the excess volume curve.

EXCESS VOLUMES OF MIXING:
The Benzene - Trichloroethylene System

By

Captain David Steven Pickerell
B.S., United States Military Academy, 1978

A Thesis Approved on

April 21, 1988
(DATE)

by the following Reading Committee:

C. A. Plank
Thesis Director, Dr. Charles A. Plank

Dr. W.L.S. Laukhuf

Dr. M.J. Maron

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of the following people, all of whom were indispensible in the completion of this thesis:

Dr. Charles Plank, for providing timely and sound guidance as well as his unique ability to motivate me and keep me encouraged.

Mr. Steve Williamson, whose ideas and assistance in the modifications, and eventual redesign and construction of the dilatometer support stand were essential.

Mr. Butch Johnson, for patiently repairing the dilatometer or installing new reference lines overnight.

My wife, Jeannette, for supporting and encouraging me every step of the way, for enduring long nights of experimentation and listening to my ideas - even when she had no concept of what I was saying.

The United States Army, for granting me the permission to persue this degree, and for paying all of my expenses in attaining it.

My God, for the provision of the above mentioned people, and so much more.

ABSTRACT

The excess volume function for the benzene + trichloroethylene (TCE) system was studied at temperatures of 10, 25, 30, and 40 ^{o}C in this investigation. Prior to describing this system, benzene + cyclohexane at 25 ^{o}C, the test system, was analyzed to determine the ability of the investigator to obtain accurate results with the apparatus and procedures described in this work. The results of the test system were in excellent agreement with those of other experimenters and with the parameters described by Handa and Benson in their summary of this system.

The excess volume function of each system studied was described by a smoothing equation that was derived from an average of 72 data points per system. All of these systems were found to have excess volume curves that were uniformly positive in shape. The benzene + TCE system at all temperatures had maximum values at about 58 percent benzene. This maximum value for the excess volume was related to temperature by the equation $V_{eT} = -.00140 * T + .653697$, where T is in K and V_{eT} is in cc/mol. The data were also checked for consistency, by the data point, by the data set, and by the system at a given temperature, with favorable results. The relationship between temperatures and excess volumes was noted to invert near both ends of the excess volume curve.

TABLE OF CONTENTS

		Page
APPROVAL PAGE		ii
ACKNOWLEDGMENTS		iii
ABSTRACT		iv
TABLE OF CONTENTS		v
LIST OF TABLES		vii
LIST OF FIGURES		ix
CHAPTER		
I.	INTRODUCTION	1
II.	BACKGROUND	3
III.	INSTRUMENTATION AND EQUIPMENT	11
IV.	PROCEDURES	19
V.	RESULTS	22
	A. DATA ANALYSIS	
	B. THE BENZENE + CYCLOHEXANE SYSTEM	
	C. THE BENZENE + TRICHLOROETHYLENE SYSTEM	
VI.	CONCLUSIONS	40
VII.	RECOMMENDATIONS	42
APPENDIX A.	DETAILED PROCEDURES	43
	A-1. BURET CALIBRATION	
	A-2. DILATOMETER CLEANING PROCEDURES	
	A-3. DILATOMETER LOADING PROCEDURES	
	A-4. TEMPERATURE CONTROL	
	A-5. OPERATING PROCEDURES	
APPENDIX B.	EXPERIMENTAL DATA	61
APPENDIX C.	CALCULATED DATA	81
	C-1. SPREADSHEET GENERATED DATA	
	C-2. MAIN FRAME COMPUTER GENERATED DATA	
APPENDIX D.	PROGRAM DOCUMENTATION	114

APPENDIX E. BURET CALIBRATION DATA 119

E-1. EXPERIMENTAL DATA
E-2. CALCULATED DATA

APPENDIX F. SAMPLE CALCULATIONS 124

APPENDIX G. NOMENCLATURE 134

BIBLIOGRAPHY 137

VITA 139

LIST OF TABLES

		Page
TABLE 1.	DATA COMPARISON FOR THE BENZENE + CYCLOHEXANE SYSTEM	28
TABLE 2.	CURVE FITTING DATA FOR THE BENZENE + TRICHLOROETHYLENE SYSTEM	30
TABLE 3.	EXPERIMENTAL DATA FOR DILUTION RUN #2	63
TABLE 4.	EXPERIMENTAL DATA FOR DILUTION RUN #3	65
TABLE 5.	EXPERIMENTAL DATA FOR DILUTION RUN #4	67
TABLE 6.	EXPERIMENTAL DATA FOR DILUTION RUN #5	69
TABLE 7.	EXPERIMENTAL DATA FOR DILUTION RUN #6	70
TABLE 8.	EXPERIMENTAL DATA FOR DILUTION RUN #7	72
TABLE 9.	EXPERIMENTAL DATA FOR DILUTION RUN #8	73
TABLE 10.	EXPERIMENTAL DATA FOR DILUTION RUN #11	74
TABLE 11.	EXPERIMENTAL DATA FOR DILUTION RUN #14	75
TABLE 12.	EXPERIMENTAL DATA FOR DILUTION RUN #15	76
TABLE 13.	EXPERIMENTAL DATA FOR DILUTION RUN #16	77
TABLE 14.	EXPERIMENTAL DATA FOR DILUTION RUN #17	78
TABLE 15.	EXPERIMENTAL DATA FOR DILUTION RUN #18	79
TABLE 16.	EXPERIMENTAL DATA FOR DILUTION RUN #19	80
TABLE 17.	CALCULATED DATA FOR DILUTION RUN #2	84
TABLE 18.	CALCULATED DATA FOR DILUTION RUN #3	86
TABLE 19.	CALCULATED DATA FOR DILUTION RUN #4	88
TABLE 20.	CALCULATED DATA FOR DILUTION RUN #5	90
TABLE 21.	CALCULATED DATA FOR DILUTION RUN #6	91
TABLE 22.	CALCULATED DATA FOR DILUTION RUN #7	93

TABLE 23. CALCULATED DATA FOR DILUTION RUN #8 94

TABLE 24. CALCULATED DATA FOR DILUTION RUN #11 95

TABLE 25. CALCULATED DATA FOR DILUTION RUN #14 96

TABLE 26. CALCULATED DATA FOR DILUTION RUN #15 97

TABLE 27. CALCULATED DATA FOR DILUTION RUN #16 98

TABLE 28. CALCULATED DATA FOR DILUTION RUN #17 99

TABLE 29. CALCULATED DATA FOR DILUTION RUN #18 100

TABLE 30. CALCULATED DATA FOR DILUTION RUN #19 101

TABLE 31. EXPERIMENTAL DATA FOR BURET CALIBRATION 121

TABLE 32. CALCULATED DATA FOR BURET CALIBRATION 123

LIST OF FIGURES

		Page
FIGURE 1.	BENZENE + CYCLOHEXANE 25 C	7
FIGURE 2.	BENZENE + PROPYLENE CARBONATE 30 C	8
FIGURE 3.	BENZENE + 1,3,5 TRIMETHYLBENZENE 27 C	9
FIGURE 4.	DILATOMETER USED IN THIS WORK	12
FIGURE 5.	DILATOMETER SUPPORT STAND	13
FIGURE 6.	BACK PRESSURE DEVICE	15
FIGURE 7.	TAMSON TCV-70 TEMPERATURE BATH	16
FIGURE 8.	NESLAB PBC 2-II BATH COOLER WITH CRYOTROL CONTROLLER	18
FIGURE 9.	BENZENE + CYCLOHEXANE 25 C, THIS WORK	29
FIGURE 10.	BENZENE + TRICHLOROETHYLENE 10 C	31
FIGURE 11.	BENZENE + TRICHLOROETHYLENE 25 C	32
FIGURE 12.	BENZENE + TRICHLOROETHYLENE 30 C	33
FIGURE 13.	BENZENE + TRICHLOROETHYLENE 40 C	34
FIGURE 14.	BENZENE + TRICHLOROETHYLENE SYSTEM	35
FIGURE 15.	EXPANDED VIEW OF FIGURE 14 (.00 TO .20) ...	37
FIGURE 16.	EXPANDED VIEW OF FIGURE 14 (.60 TO 1.00) ..	38
FIGURE 17.	RUN #17, DATA POINT #1	127
FIGURE 18.	RUN #17, DATA POINT #2 BEFORE PRESSURE CORRECTION	128
FIGURE 19.	RUN #17, DATA POINT #2 AFTER PRESSURE CORRECTION	129
FIGURE 20.	MERCURY DENSITY BETWEEN 20 AND 30 C	132

CHAPTER I

INTRODUCTION

When mixing two miscible liquids of known volume, the volume of the resultant mixture frequently differs from the sum of the two known component volumes. This difference is known as the excess volume of mixing.

This volume change on mixing can be caused by a vareity of geometric, energetic, and chemical means. Because of the complex nature of the factors giving rise to excess volumes of mixing, accurate excess volume data can be used to test theories of liquid mixtures. Excess volume data can also be used to convert other excess functions evaluated at constant pressure to their equivalent expressions in terms of mixing at constant volume; most notably, the excess Gibbs free energy can be related to the excess volume of mixing through the equation: (Prausnitz, p. 196)

$$V^E = \left(G^E / P \right)_{T,x} \qquad (1)$$

Where: V^E is the excess volume

G^E is the excess Gibbs free energy

P is pressure

Note: The right hand quantity is measured at constant temperature (T) and composition (x).

Additionally, excess volume data can be used industrially to accurately determine the quantities of liquids necessary to be mixed in order to yield a mixture of precise

composition and volume. It can also be used to determine composition from the density measurements of a mixture. (Handa, p. 186)

CHAPTER II

BACKGROUND

For the purposes of this discussion, a binary mixture will be defined as a physical, non-reactive combination of two components in a single fluid phase. There exist thermodynamic properties of each particular mixture that distinguish it from any other mixture of the same two components. These properties can be divided into two broad categories: intensive and extensive. An extensive property is one that depends on the amount of material present. These properties include total mass (M), total volume (V), enthalpy (H), entropy (S), and Gibbs free energy (G). An intensive property, on the other hand, is independent of the amount of mixture present. Temperature (T), total pressure (P), specific volume (v), and density (ρ) are examples of intensive properties. Due to their intensive nature and ease of measurement, most of the other properties are described as functions of temperature and pressure.

Additionally, although much information is generally known about single component system properties, relatively little is available on the properties of mixtures. Therefore, it is helpful to discuss the properties of mixtures in terms of the pure component properties. One way of doing this is to define a reference, or standard, state as the pure component at the temperature and pressure of the

system. This standard state is referred to as "Raoults Law" standard state (Prausnitz, pp. 21-22) and will be used throughout this work.

For an ideal solution to exist, the total volume of the solution must be equal to the sum of the total component volumes. In terms of molar volumes:

$$V^{ID} = \sum x_i \, V_i^{o} \tag{2}$$

where: V^{ID} is the total molar volume of an ideal solution

V_i^{o} is the molar volume of component i in solution

x_i is the mole fraction of component i in solution

Ideal behavior is seldom observed in real solutions. Therefore, a correction factor needs to be included. (Smith, p. 245)

$$V = \sum x_i \, V_i^{o} + \Delta V \tag{3}$$

where: V is the total molar volume of a real solution

ΔV is the molar volume change on mixing

A measure of the deviation of a solution from ideal behavior is the excess volume, which is defined as: (Smith, p. 266)

$$V^{E} = V - V^{ID} \tag{4}$$

where: V^{E} is the total molar excess volume of a solution

It is convenient at this time to introduce the concept of partial molar volumes. (Prausnitz, p. 196)

$$\bar{V}_i = \left| \partial nV / \partial n_i \right|_{T,P,nj} \tag{5}$$

where: $\bar{V}_i$ is the partial molar volume of component i

Note: This volume is calculated at conditions of constant temperature, pressure, and total moles of all components except that of component i.

This concept is particularly useful in that for all solutions at constant temperature and pressure:

$$V = \sum x_i \bar{V}_i \tag{6}$$

Now, referring to equations 3 and 4,

$$V^E = (\sum x_i V_i^o + \Delta V) - \sum x_i V_i^o \tag{7}$$

Further simplification yeilds

$$V^E = \Delta V \tag{8}$$

Equation 8 results since, by definition, $\Delta V^{ID} = 0$, (Prausnitz, p. 195) and thus, the excess volume is not a "new" property. Other excess properties, for example, the excess Gibbs free energy, are different from the change in the property on mixing.

By definition of Raoult's standard state,

$$\bar{V}_i^{ID} = V_i^o \tag{9}$$

Since equation 6 applies to all mixtures and with equations 2 and 9,

$$V^{ID} = \sum x_i \bar{V}_i = \sum x_i V_i^o \tag{10}$$

is another way of defining an ideal solution.

Since $V^E = \Delta V$, if the molar volume change on mixing can be determined experimentally, so can the excess molar volume of mixing. Thus, a measure of the deviation of a solution from ideal behavior can be determined.

Experimental data for molar excess volumes of binary

solutions are usually fit to a smoothing function of form: (Handa, p. 200)

$$V^E = x_1 (1 - x_1) \sum_{j=0}^{n-1} a_j (1 - 2x_1)^j \quad (11)$$

where: a_j are the fitting constants determined by a least-squares analysis

n is the number of coefficients

The units of V^E are generelly cc/mol.

The number of coefficients to be used in smoothing the data is determined by carrying out the least-squares analysis for increasingly larger values of n. Usually, n varies from 2 to 5. For each fit, a standard deviation is calculated.

$$\sigma = [\sum_{i=1}^{n} (V_i^E \text{ observed} - V_i^E \text{ smoothed})^2 / (m - n)]^{1/2} \quad (12)$$

where: m is the number of experimental data points

The minimum number of coefficients is selected for the smoothing equation that will yield the lowest population standard deviation.

This curve fitting technique is extremely flexible and capable of describing most of the possible excess molar volume curve types. As noted in Figures 1, 2, and 3, excess volume data can be uniformly positive, uniformly negative, or can have both a minimum and a maximum while changing sign somewhere in the middle of the mole fraction range.

Although quite a large number of binary systems have been studied, relatively few or them have been investigated over a wide range of temperatures. The bulk of the excess volume research has been conducted near 25 or 30 ^{o}C. For

FIGURE 1

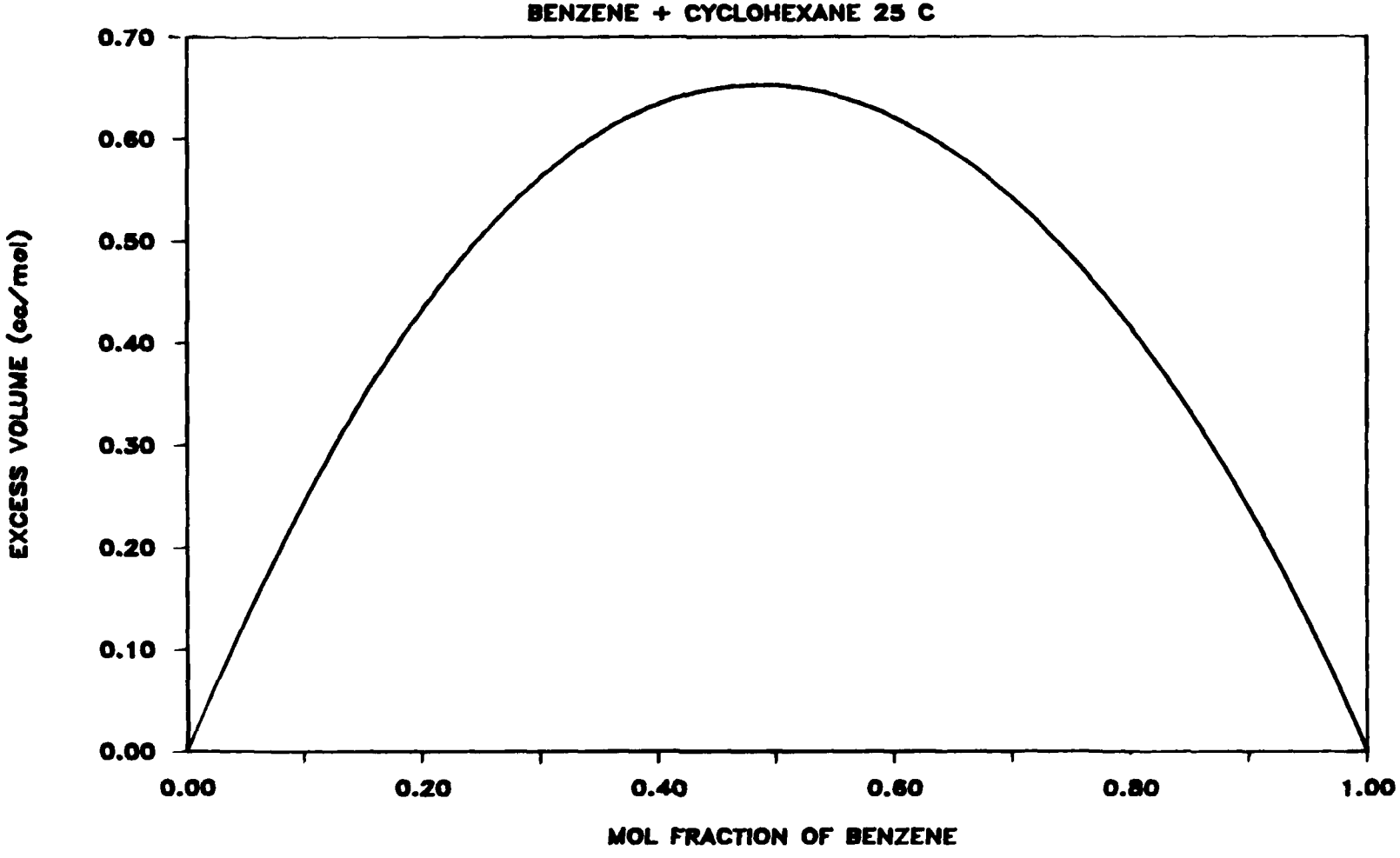

BENZENE + CYCLOHEXANE 25 C
EXCESS VOLUME (cc/mol)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.20
0.40
0.60
0.80
1.00
MOL FRACTION OF BENZENE

FIGURE 2

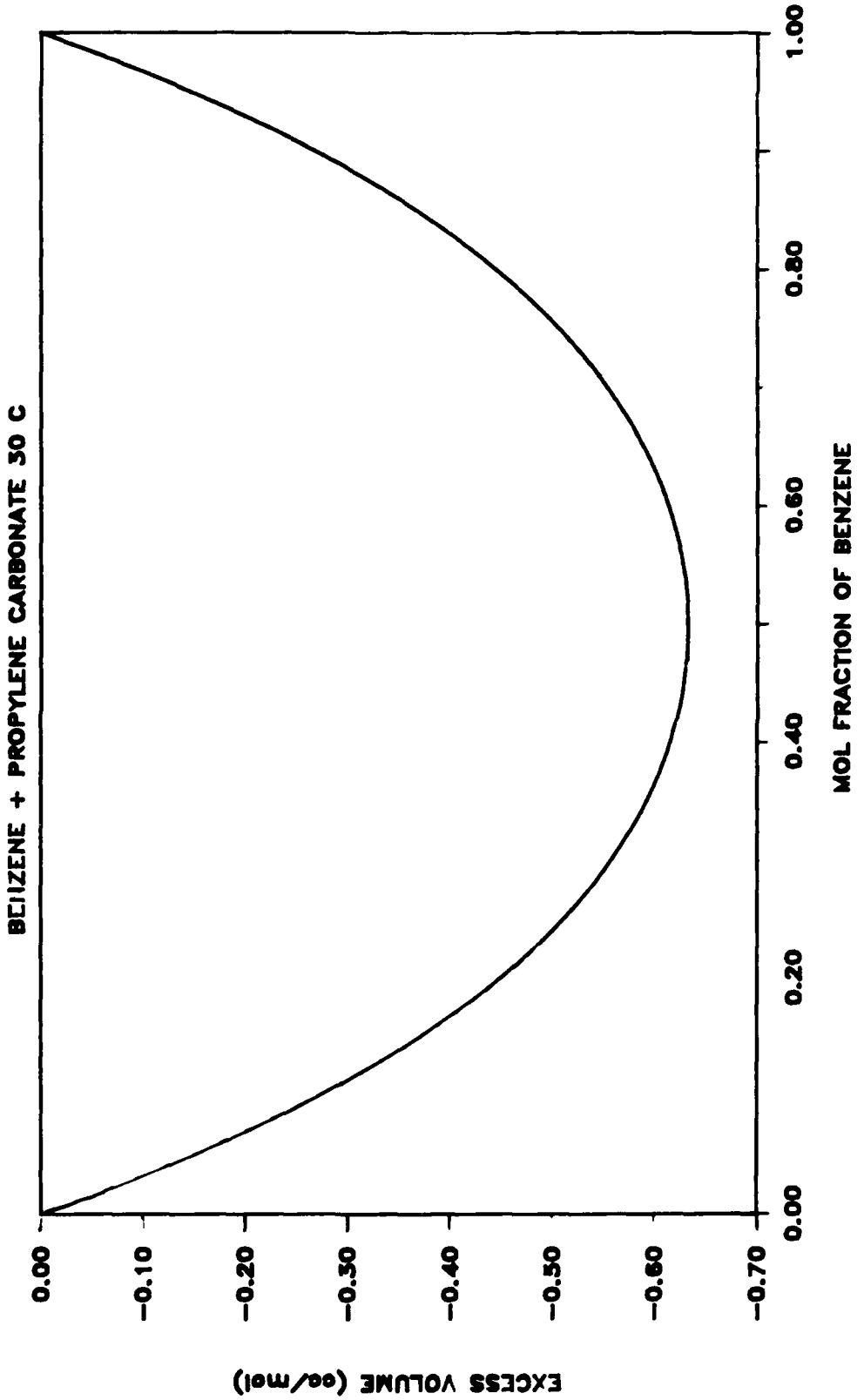
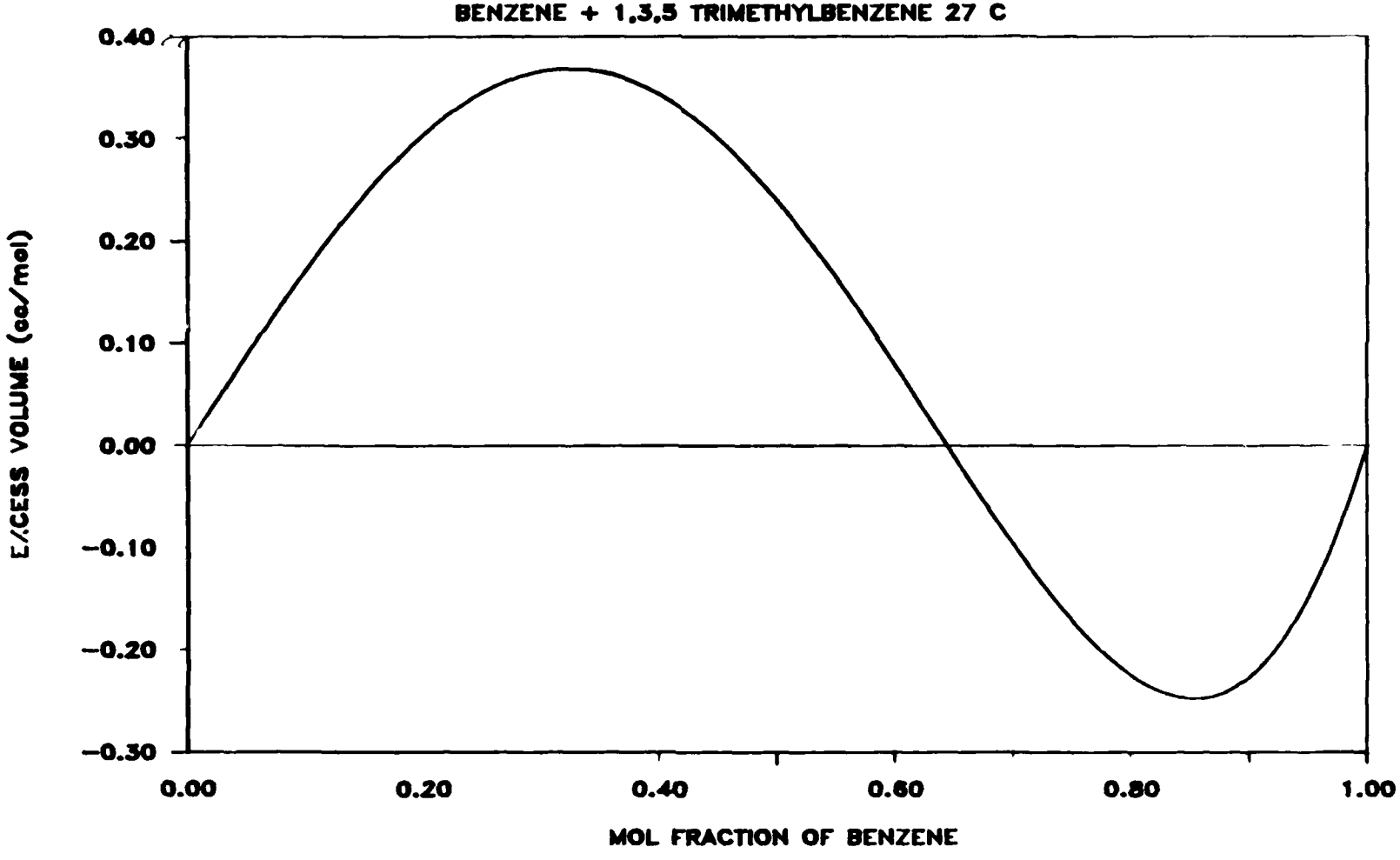

BENZENE + PROPYLENE CARBONATE 30 C
EXCESS VOLUME (cc/mol)
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
0.00
0.20
0.40
0.60
0.80
1.00
MOL FRACTION OF BENZENE

FIGURE 3


BENZENE + 1,3,5 TRIMETHYLBENZENE 27 C
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
EXCESS VOLUME (cc/mol)
0.00
0.20
0.40
0.60
0.80
1.00
MOL FRACTION OF BENZENE

those systems that were studied at several temperatures, there appears to be no discernable trend of the data with increasing temperature.

The purpose of this thesis was twofold. First, to investigate the benzene + cyclohexane system at 25 ^{o}C for the purpose of establishing a comparable level of accuracy for the procedures and equipment used in this investigation. And second, to investigate the benzene + trichloroethylene system at a variety of temperatures to determine the significance of temperature change on this previously unstudied system.

As an aside, this investigation also focused on improving the apparatus and procedures previously set out in an effort to improve the accuracy of the experimental data. Where appropriate, the significant improvements and lessons learned will be noted.

CHAPTER III

INSTRUMENTATION AND EQUIPMENT

The dilatometer used in this investigation, shown in Figure 4, was essentially that designed by Kumaran and McGlashan (Kumaran, pp. 260-262), with a few modifications. The capillary tubes, noted as C, C1, and C2, were precision bore capillaries with a .05 millimeter inside diameter. Capillary C had a reference mark CR near the bottom. The buret, labeled B, was one centimeter precision bore tubing. The bulb at the bottom of the buret, BB, was a blown glass bulb with a volume of about 10 cc below the reference mark BR. Mixing bulb A and tubes S1 and S2 were not calibrated. The taps, T1 and T2, were Teflon and had Buna-N O-rings midway up the shaft. Tap T2 also had a level bubble attached to its screw cap. The small addition on top of capillary C was half of a ground glass joint that was attached to capillary C by a small piece of Tygon tubing. The back-pressure device discussed later was attached to the dilatometer at this joint. The dilatometer was assembled by Custom Glassblowing of Louisville.

A plexiglass frame shown in figure 5 was built to support the dilatometer. Two of the three support blocks on the frame were adjustable from the top so the dilatometer could be leveled while it hung in the temperature bath. A thermometer was also affixed to the stand for monitoring the

FIGURE 4

DILATOMETER USED IN THIS WORK

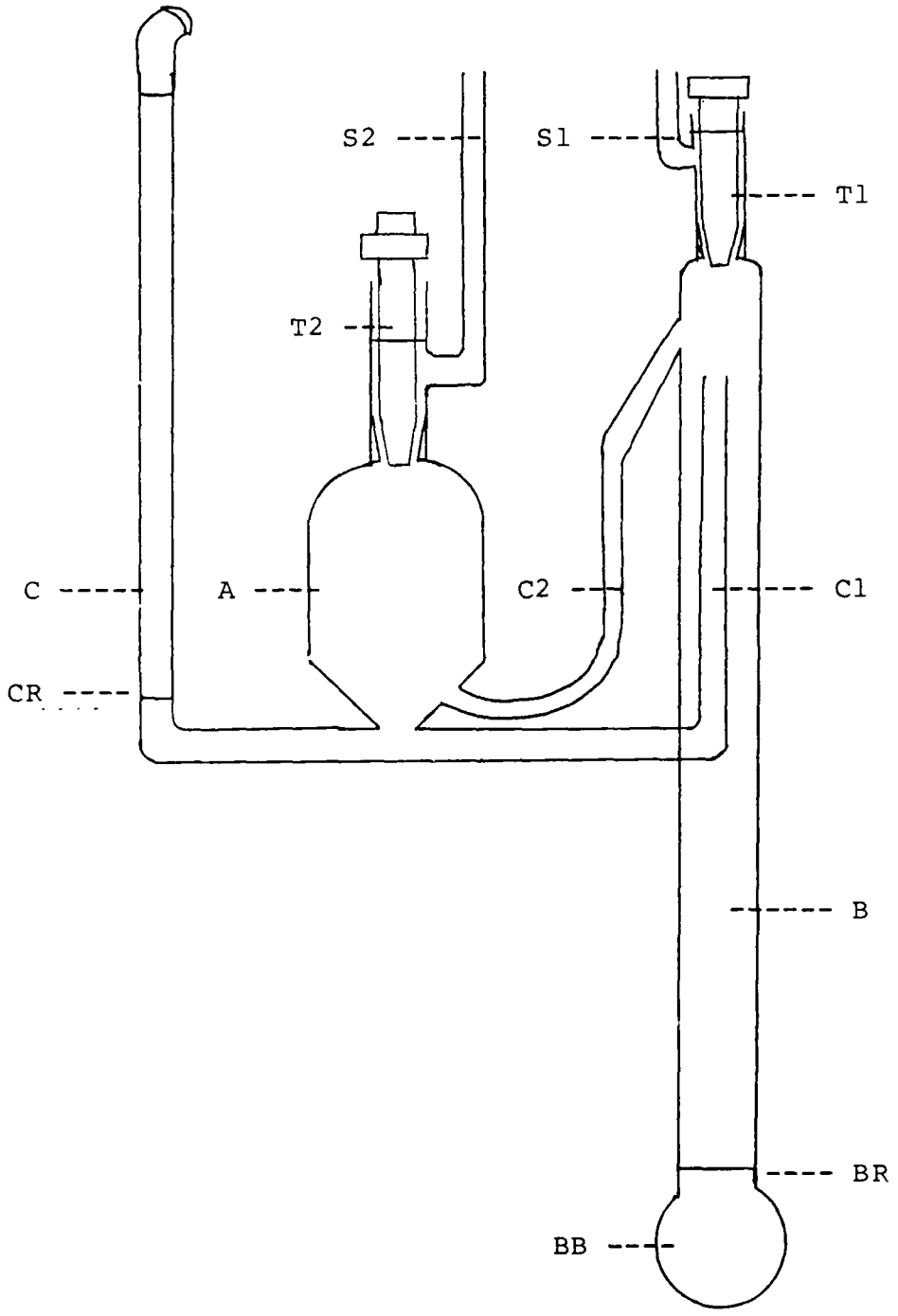
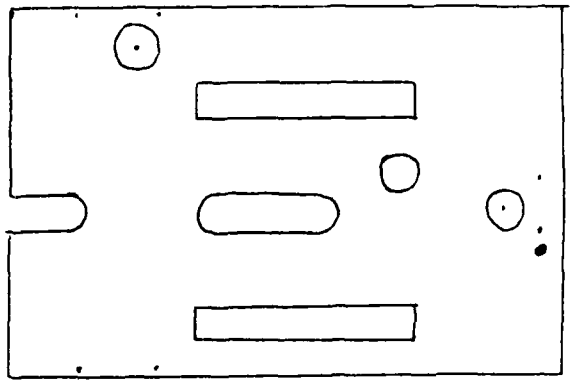
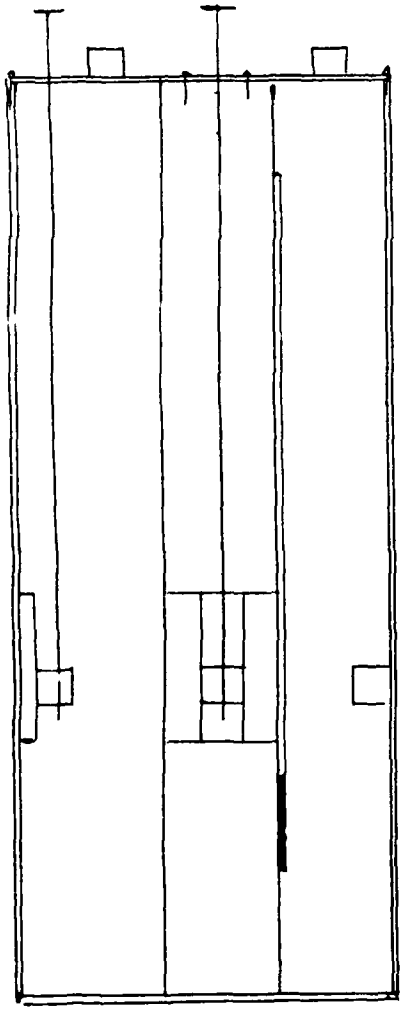


FIGURE 5

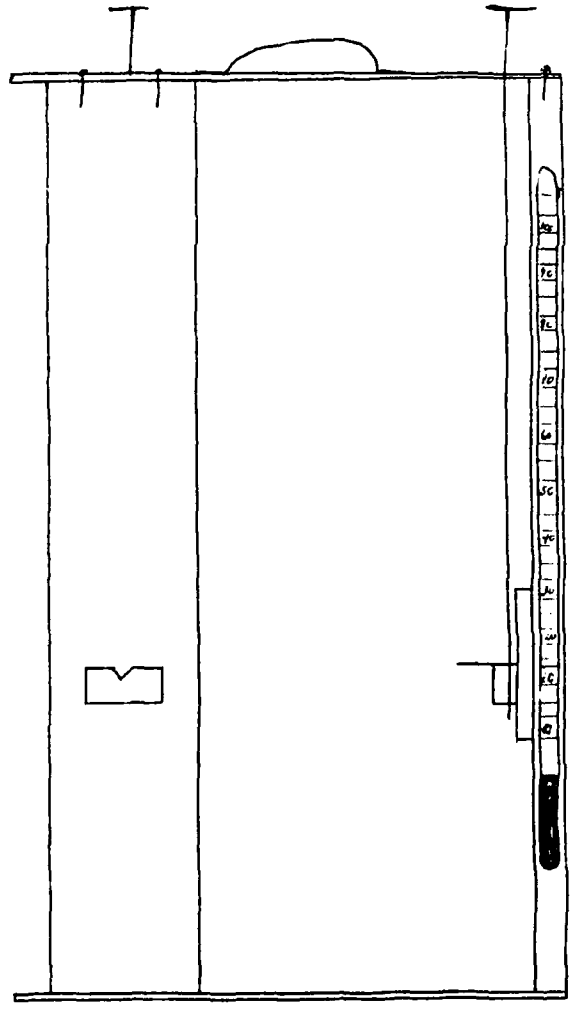
DILATOMETER SUPPORT STAND



TOP VIEW



LEFT SIDE VIEW



FRONT VIEW

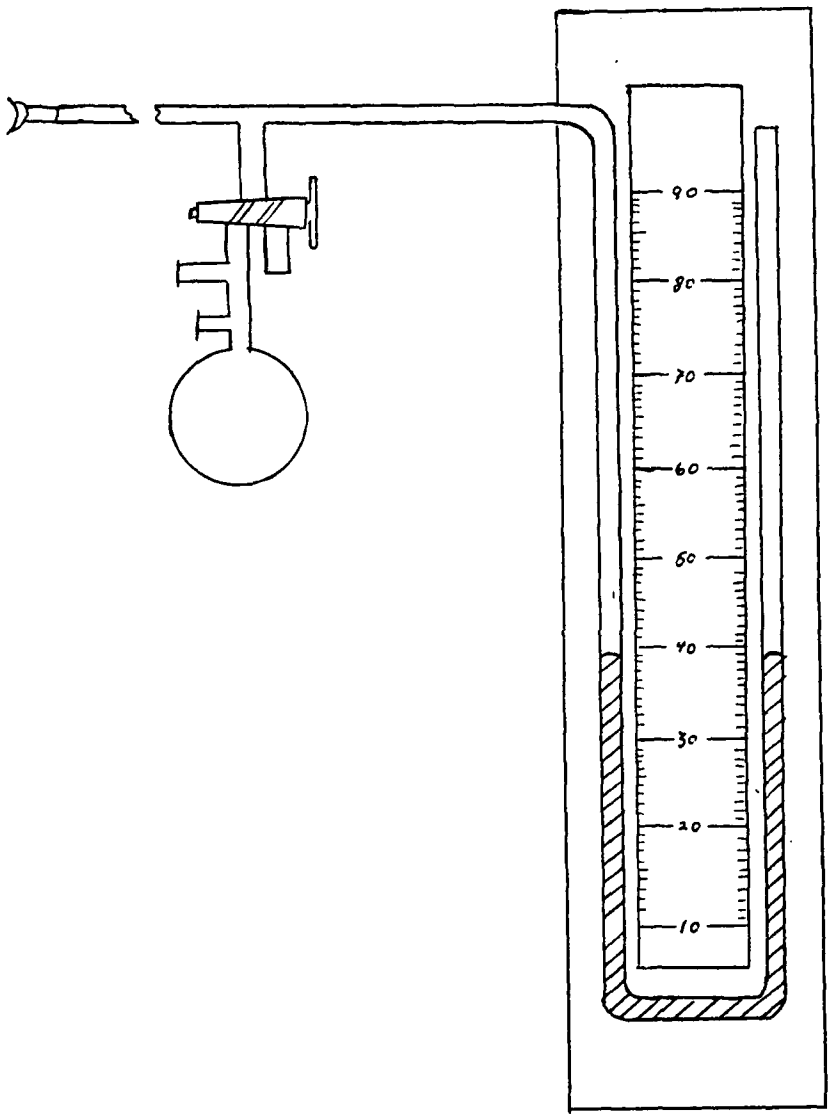
temperature of the water in the bath. The dilatometer was mounted to a rectangular piece of plexiglass with copper wire so that the dilatometer could be easily separated from the plexiglass for cleaning and glassblowing, as necessary. The rectangular plate had a small cross member attached to the bottom so the dilatometer would fit neatly into the support stand.

The back-pressure device shown in Figure 6 was constructed to apply a measurable pressure on the column of mercury in capillary C in order to calculate pressure corrected excess volume data. This device consisted of a U shaped tube that was partially filled with mercury. One end of the tube was vented to the room, while the other was connected to a "T" joint. Also attached to this joint were a three lead stopcock and a piece of Tygon tubing with half of a ground glass joint on the end. The second lead of the stopcock was vented to the air, while the remaining lead was attached to an aspirator bulb. The ground glass joint on the Tygon tubing was used to connect the back-pressure device to capillary C on the dilatometer.

The temperature bath used in this investigation was a Tamson model TCV-70 temperature bath with glass panes on two sides and is shown in Figure 7. Distilled water was used as the heat transfer medium in the bath. There were two heating units inside the bath. The main heating unit was a quartz heater with adjustable heating capacity. The secondary heating element was a more standard metal

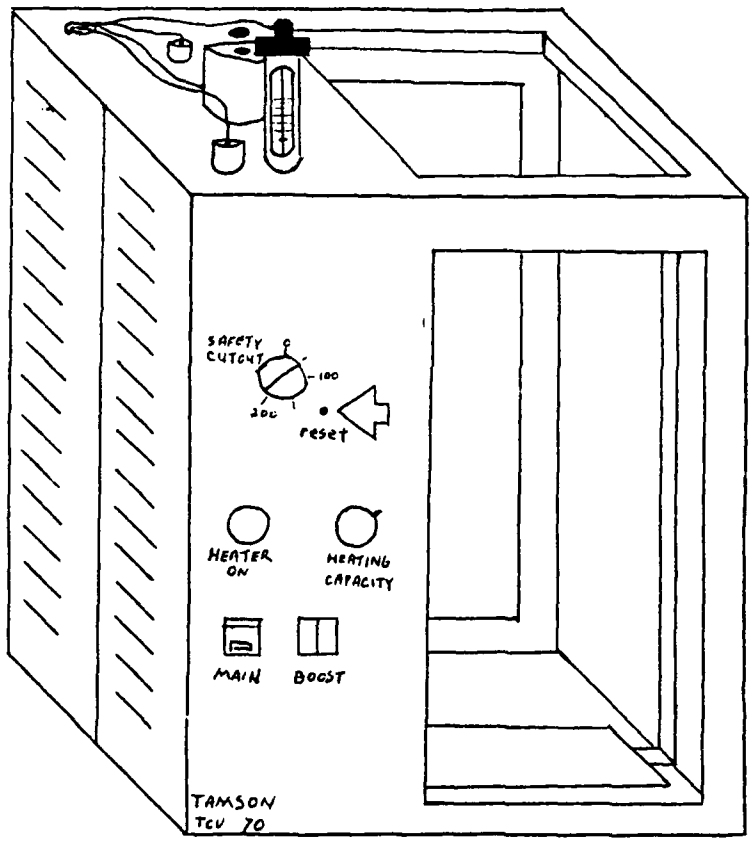
FIGURE 6

BACK-PRESSURE DEVICE



FICURE 7

TAMSON TCV-70 TEMPERATURE BATH



resistance-type element that was used only as a boost heater to help bring the bath initially to a temperature near the set point. There was also a propeller and baffle assembly to circulate the water and keep the temperature uniform throughout the bath. The temperature was controlled by means of a thermoregulator which protruded through the top of the bath. By carefully setting the controls on the bath, one could control the temperature to ± .001 ^{o}C of the set point value.

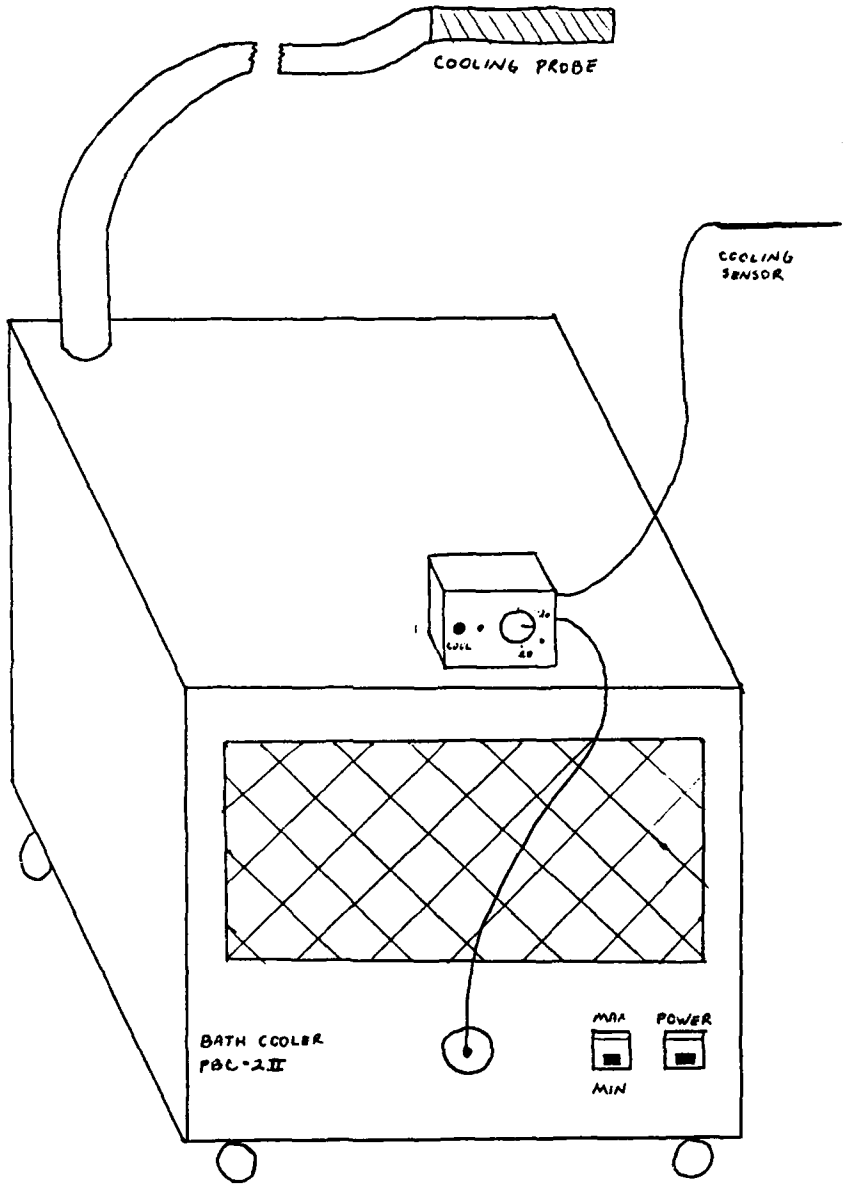
When cooling was required, the Neslab PBC-2 II portable bath coolerin Figure 8 was used in conjunction with a Cryotrol temperature controller. The cooling probe was inserted through an opening in the top of the temperature bath and the temperature sensor was inserted through a small hole in the top of the dilatometer support stand.

All weights were measured with an Ainsworth model Delta N-V (Type 24N) scale. This scale had a digital readout to ± .00001 grams, with the last two digits being read on a vernier scale.

Height measurements were made with the use of cathetometers. A Gaertner Scientific Corporation precision cathetometer was used to measure all heights except those on the buret. This cathetometer could be read to ± .0001 cm, with the last digit being read on a vernier scale. The height measurements on the buret were made with an Eberbach cathetometer that could only be read to ± .01 cm, with the last digit being read on a vernier scale.

FIGURE 8

NESLAB PBC 2-II BATH COOLER WITH CRYOTROL CONTROLLER



CHAPTER IV

PROCEDURES

A detailed, step by step, account of the procedures followed during this thesis work is located in Appendix A. The buret was recalibrated before the excess volume experimentation began, although this is unnecessary unless a previous calibration is suspect or the volume of the bulb has changed due to glassblowing.

First, the system to be studied was specified. This included selection of the operating temperature as well as the two components of the binary system.

Next, one of the components was designated (arbitrarily) as the solvent and the other as the solute. Upon completion of a run, these roles were reversed, and the next run begun.

The condition of constant operating temperature was then achieved in the temperature bath. This was accomplished by adjusting the screw cap on the thermoregulator and the heating capacity control on the temperature bath. If cooling was necessary, the bath cooler controls were also adjusted.

The dilatometer was next cleaned and loaded. All initial readings were recorded at this time. Care was taken to ensure that thermal equilibrium was reached before any readings were made. Generally, about 20 minutes were

required to reach thermal equilibrium.

Next, with the buret on the right, the dilatometer was tilted clockwise such that a small amount of mercury spilled into the buret. The dilatometer was then placed back in the temperature bath and thermal equilibrium was again reached. All mercury levels were then recorded with respect to the appropriate reference mark.

A pressure correction was then conducted by placing a known back-pressure on the system and measuring its effect. This correction is an essential factor in the excess volume data for two reasons. First, there may be some small amount of gas bubbles entrained in the system which, if not corrected for, could expand and influence the data. Also, with taps T1 and T2 sealed, pressure differentials can be set up within the dilatometer by virtue of the differing mercury column heights.

The tilting of the dilatometer and measurement of the mercury levels was repeated successively until the capacity of the dilatometer was reached. Then the roles of the solvent and the solute were reversed, and the experiment was repeated.

Finally, the data were evaluated for internal consistency as well as consistency between data sets. If these evaluations proved unsatisfactory, additional data were taken as required to achieve the desired level of agreement.

The benzene used in this investigation was a glass-distilled, 99.9 + % pure Aldrich product. The densities

used for the benzene were: .8895 cc/mol at 10 ^{o}C, .8790 cc/mol at 25 ^{o}C, .8684 cc/mol at 30 ^{o}C, and .8577 cc/mol at 40 ^{o}C. (API 44 Tables).

The trichloroethylene used here was a 99 + %, ACS reagent grade product of Aldrich. The densities used here were: 1.4825 cc/mol at 10 ^{o}C, 1.4554 cc/mol at 25 ^{o}C, 1.4475 cc/mol at 30 ^{o}C, and 1.4300 cc/mol at 40 ^{o}C. (Gallant, p. 42).

The cyclohexane used in this work was a 99.9 + % pure product of Burdick and Jackson. At 25 ^{o}C, the density of cyclohexane is .7739 cc/mol.

CHAPTER V

RESULTS

A. Data Analysis.

A total of 19 runs were made for this thesis, three for the test system, benzene + cyclohexane, and 16 for the benzene + trichloroethylene system. The experimental data for each run were initially written in a data log. The purpose of run one was primarily to get familiar with the operating requirements of the system. The data for this run were discarded for numerous procedural errors that obviously effected the results. The data for runs number 9, 10, and 13 were also discarded because various parts of the dilatometer broke during each run. In run 9, tap T1 was broken into two parts under the O-ring. In run 10, the magnetic stirrer initially located inside the mixing bowl developed a crack and had to be removed. In run 13, capillary C broke where it joined the horizontal tube. Additionally, runs 9 and 12 were discarded because of degassing problems which left large gas bubbles inside the buret after the run had started. No further data analysis was performed on these five runs.

The data for the remaining 14 runs were transcribed to a computer spread sheet for further analysis. These data are located in Appendix B. With the aid of the spread sheet, the mole fraction and excess volume data could be

calculated immediately after each data point was recorded, as shown in Appendix C-1. These data are reported here without regard for significant figures, which will be addressed separately. Generally, two sets of data were required to sufficiently specify the excess volume curve for a given temperature and set of components. However, late in runs 15 and 18, a small amount of solute escaped from the mixing bowl during a tilt. This caused a separation in the mercury column in capillary C and would also have resulted in a miscalculation of the amount of solute added to the mixing bowl if the runs were continued beyond that point. This error apparently resulted from rotating the dilatometer too far during the tilt. Because of this problem, three sets of data were required to specify the curves of the benzene + trichloroethylene system at 10 and 40 ^{o}C. Run 7 was also terminated prematurely due to degassing problems, but there were several good data points available, so runs 7 and 8 were combined for further analysis.

The remaining data sets were grouped by temperature and component systems. Set one was benzene + cyclohexane at 25 ^{o}C, runs 2 and 3. Set two was benzene + trichloroethylene at 25 ^{o}C, initially runs 4 and 5, although set two was eventually comprised of runs 5 and 6. Set three was benzene + trichloroethylene at 30 ^{o}C, runs 7, 8, and 11. Set four was benzene + trichloroethylene at 40 ^{o}C, runs 14, 15, and 16. Finally, set five was benzene + trichloroethylene at 10 ^{o}C, runs 17, 18, and 19. The mole fraction and excess volume

data from these sets were converted into data files using the program "Makefile". These files were then accessed by the program "Curvfit" which yielded the curve fitting constants as described in the Background section of this work. A listing of these programs is found in Appendix D. The program "Curvfit" was run for curve fitting constants ranging from 2 to 5. The set of constants yielding the lowest population standard deviation was then used to describe the smoothing function. These data are presented in Appendix C-2.

Additionally, several data consistancy checks were made. First, an internal consistancy check was made using the population standard deviation. A population standard deviation above that reported by other investigators measuring excess volume data, greater than .01, would warrant a set of runs being discarded. Next, consistency between data runs in a set was investigated. If the data points in the overlap region between the two runs were offset, the more suspect run would be done over, and a new pairing made. Finally, consistency between successive data points was checked. This was accomplished by eliminating the data point that differed the most from the smoothing function and re-running the "Curvfit" program. Then, the next worse data point would be removed, and so on until ten percent of the data points had been removed, one at a time. If a clustering of bad data points was observed, the run in which this clustering occurred would be thrown out. This was the

case with run 4, where the entire set of eliminated data points fell in succession. Run 4 was discarded, and run 6 was conducted to take its place.

Finally, as the data points were eliminated during the consistency checks, any change in the population standard deviation was noted. If the elimination of one or more data points caused a reduction in the standard deviation of .002 cc/mole or more, the points were permanently removed from the data set as erroneous data. This was only done in the benzene + cyclohexane system at 25 ^{o}C where 106 data points were initially taken, but 10 were thrown out due to error. Regardless of analytical technique, if a data point was obviously in error, it was eliminated as long as ten percent or less of the data in a complete set was discarded.

In fitting the data to a smoothing equation, it was noted that the coefficient matrix had a propensity toward being ill conditioned. With this in mind, the data were actually fit as $V_e/(x1x2)$ as opposed to V_e in an effort to eliminate some of the ill conditioning. The L_1 condition number (a measure of the tendency to lose significant figures in certain matrix operations) was also estimated and reported. It should be noted that if the condition number is written as $C * (10)^n$ it should be expected that the last n significant digits of the final answer may be in error (Maron, pp. 159-160). Where possible, 6 digits were carried forward in an effort to preserve the accuracy of the final data presented by the output from the "curvfit" program.

The worst condition number reported in this work was 593 for the benzene + trichloroethylene system at 40 °C. This would indicate that 2 significant digits might be eliminated. However, it should be recalled here that the cathetometer used to read the height measurements on the buret was only accurate to within .01 cm. For the data reported here, this level of accuracy translates to only three significant digits for mole fractions of benzene less that .20 or greater than .80, and four significant digits for the rest of the data range. This indicates that the ill conditioning of the coefficient matrix did not affect the results of this investigation, but might well affect the results of further investigations if the accuracy of this cathetometer is improved.

It should be noted here that when all five systems studied in this work are compared, the population standard deviation generally decreases when the number of data points taken increases. Also, for the same number of curve fitting constants, the L_1 condition number is smaller for a larger number of data points.

Minor temperature fluctuations appeared to have little effect on the results. Although the thermometers used to monitor each system varied from a National Bureau of Standards calibrated thermometer graduated in .05 °C increments for the 25 °C runs, to an uncalibrated thermometer graduated in .1 °C increments for the 10 and 40 °C runs, the standard deviations show no trend with degree of accuracy of

the thermometer. This is attributed to the fact that the bath was able to control the temperature consistently better than any of the thermometers could measure it. The actual temperature at which the run was conducted may be questionable, but the consistency of the data due to temperature fluctuation was excellent. Runs 1 through 6 were conducted at better than 25 ^{o}C $\pm$ .01 ^{o}C, (thickness of the marks on the thermometer was the determining factor here). Runs 7 through 11 were conducted at 30 ^{o}C $\pm$ .05 ^{o}C, due to lack of thermometer calibration. Runs 12 through 16 were conducted at 40 ^{o}C $\pm$ .1 ^{o}C and runs 17 through 19 were conducted at 10 ^{o}C $\pm$ .1 ^{o}C, again due in part to the lack of NBS calibration and also to the level of graduation being .1 ^{o}C.

B. The benzene + cyclohexane system.

The benzene + cyclohexane system at 25 ^{o}C has been proposed as the test system for excess volume data. Such a great volume of data has been reported on this system that it is possible to measure the accuracy of the equipment and experimental technique used in an investigation. Once an accuracy level has been established for this system, an investigator may ascribe the same level of accuracy to all new data he generates with the same apparatus and technique.

Handa and Benson went to great lengths to document the test system parameters in their work. (Handa, pp. 200-205) Table 1 contains a comparison between the data generated in this investigation, the summary of Handa and Benson, and a summary of 14 other works. There were 106 data points taken

in this work in an effort to accurately describe this system. The average number of data points used in the 14 other works was about 34. Handa and Benson used a composite of three works judged by them to be the best and most representative data available. There were 164 data points total among these three data sets. Comparison 1 in Table 1 was based on a least-squares curve fit with all 164 data points weighted equally. Comparison 2 in Table 1 was based on a least-squares curve fit with each of the 164 data points being assigned a weight equal to the inverse of the squared standard deviation of that point from the smoothed curve in the work from which it was taken.

TABLE 1

DATA COMPARISON FOR THE BENZENE + CYCLOHEXANE SYSTEM

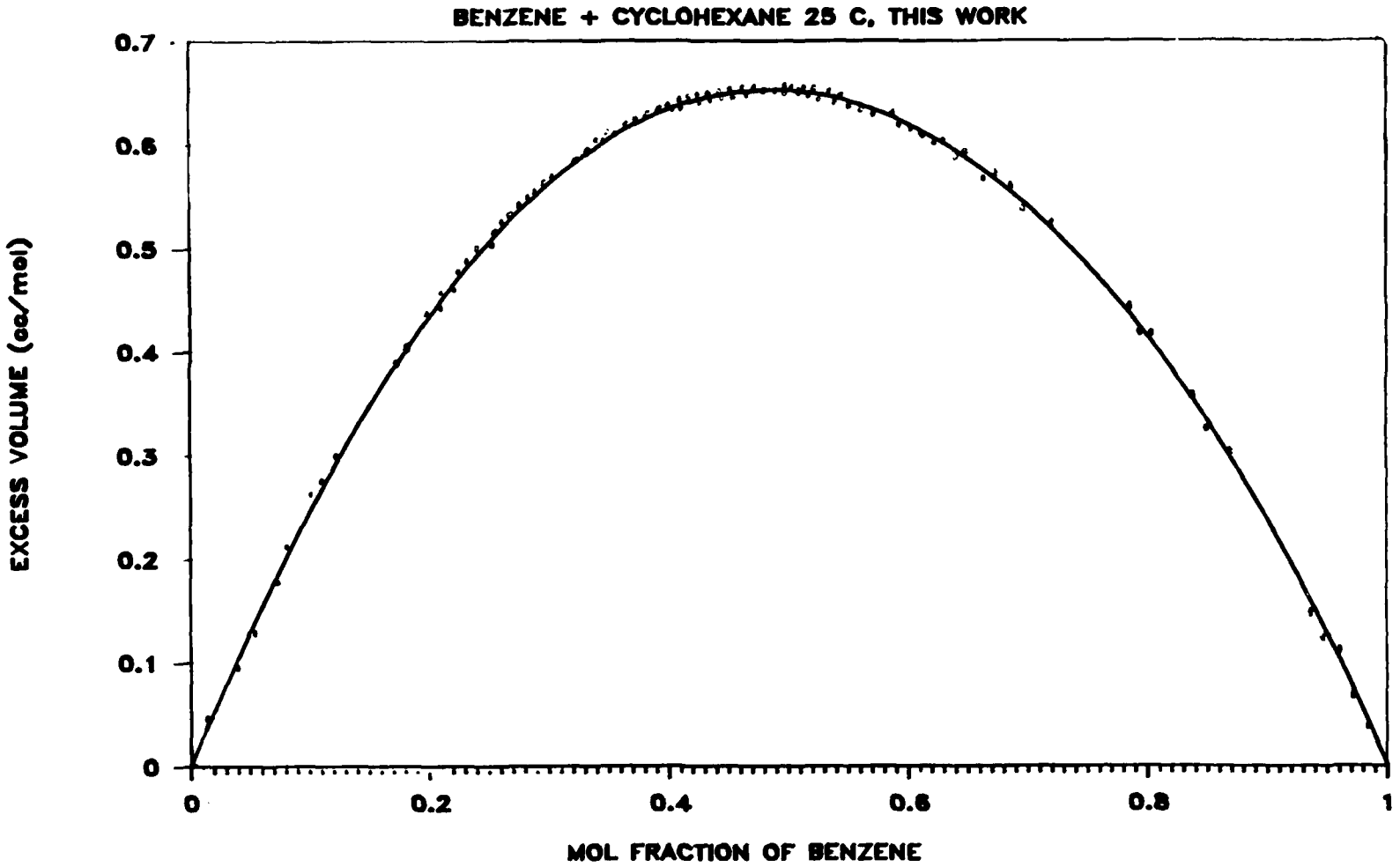
	Std dev. (cc/mol)	Location of max.	V^E at max. (cc/mol)	V^E at .5 (cc/mol)
This work	.00275	.485	.6529	.6523
Handa & Benson Comparison 1	.00157	.491	.6511	.6509
Handa & Benson Comparison 2	.00161	.491	.6520	.6518
Range of Other Works	.00003 - .0050	.485 - .494	.6315 - .6555	.6312 - .6552

Figure 9 shows the smoothed excess volume curve calculated in this work. The equation for this curve is:

$$V^E = x_1 (1 - x_1) [2.6092 + .15423(1 - 2x_1) + .12096(1 - 2x_1)^2 - .14836(1 - 2x_1)^3]$$

The experimental data upon which this curve was based are

FIGURE 9


BENZENE + CYCLOHEXANE 25 C, THIS WORK
EXCESS VOLUME (cc/mol)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

superimposed on the figure in an effort to show how well the smoothed curve actually describes the data. There is no point in presenting a figure comparing this work to the data presented by Handa and Benson because the curves are indistinguishable on any reasonable scale.

C. The benzene + tricloroethylene system.

It should be noted first, that although the accuracy of these data cannot be shown directly by comparison with known values, it can be inferred from the accuracy of the benzene + cyclohexane system discussed above.

Figures 10 through 13 are the smoothed curves describing the benzene + trichloroethylene system at 10, 25, 30, and 40 ^{o}C, respectively, as calculated in this work from the equation:

$$V^{E} = x_1 (1 - x_1)[a_o + a_1 (1 - 2x_1) + a_2 (1 - 2x_1)^2 + a_3 (1 - 2x_1)^3 + a_4 (1 - 2x_1)^4]$$

Table 2 contains the curve fitting constants used to calculate these curves, and the standard deviation from the fit for each temperature.

All four of these curves are overlaid in Figure 14 for comparison. There was little utility in describing the curves at both 25 and 30 ^{o}C, as there was very little change between the two sets of data. In fact, throughout much of the range of these two curves, they are sufficiently close that the standard deviations of each data set could cause these sets to become intertwined.

FIGURE 10

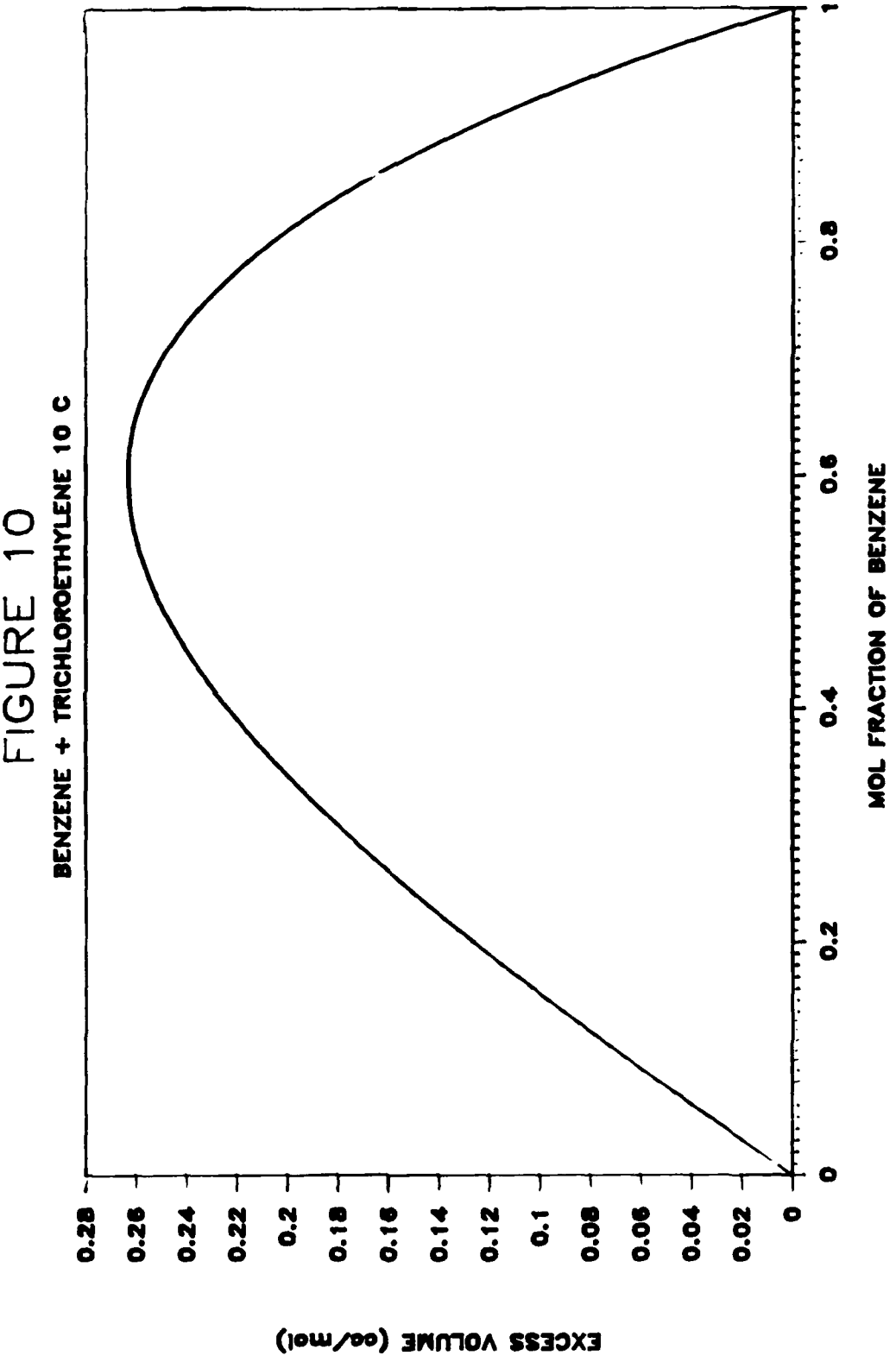

BENZENE + TRICHLOROETHYLENE 10 C
EXCESS VOLUME (cc/mol)
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

FIGURE 11

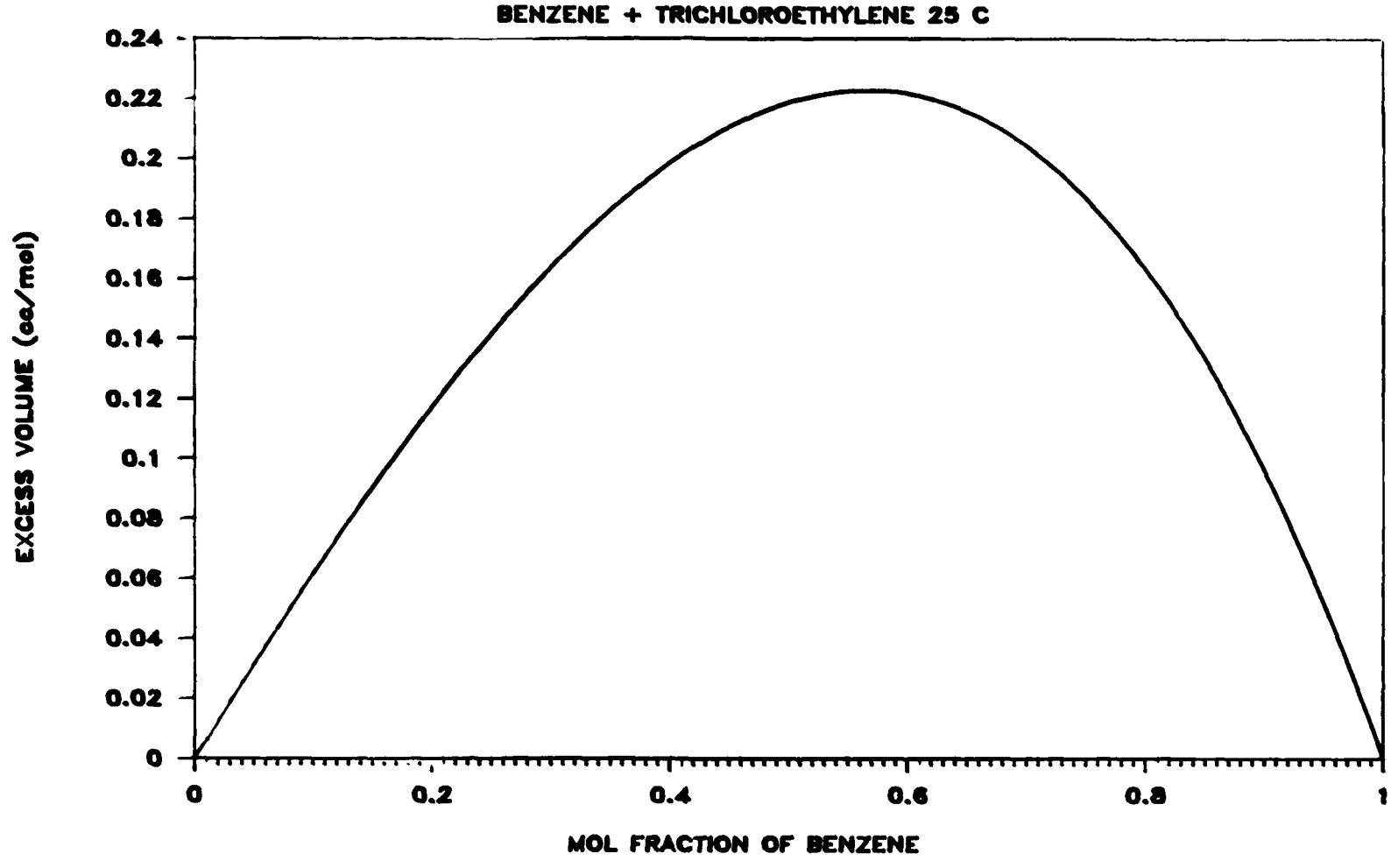

BENZENE + TRICHLOROETHYLENE 25 C
EXCESS VOLUME (cc/mol)
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

FIGURE 12

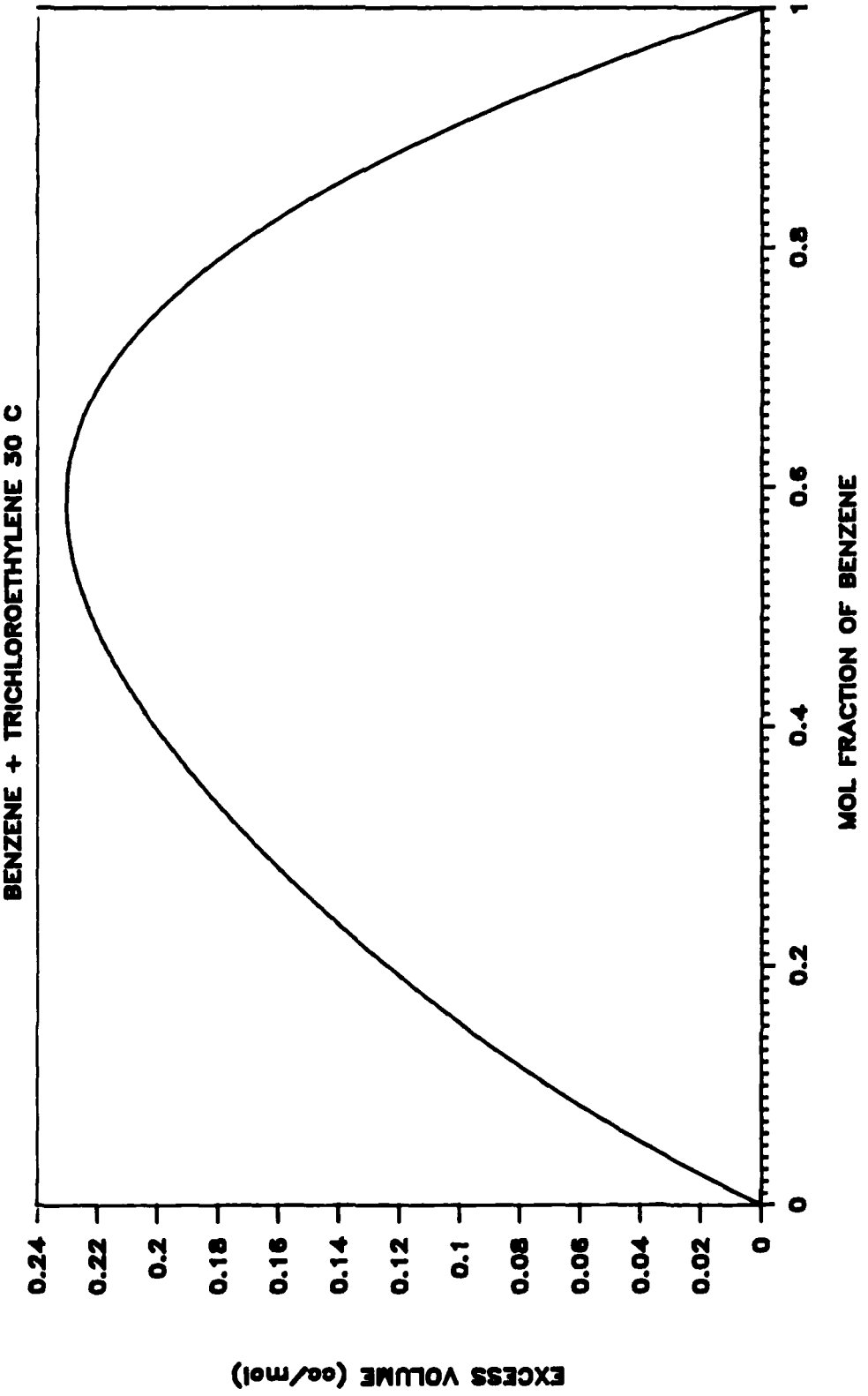

BENZENE + TRICHLOROETHYLENE 30 C
EXCESS VOLUME (cc/mol)
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

FIGURE 13

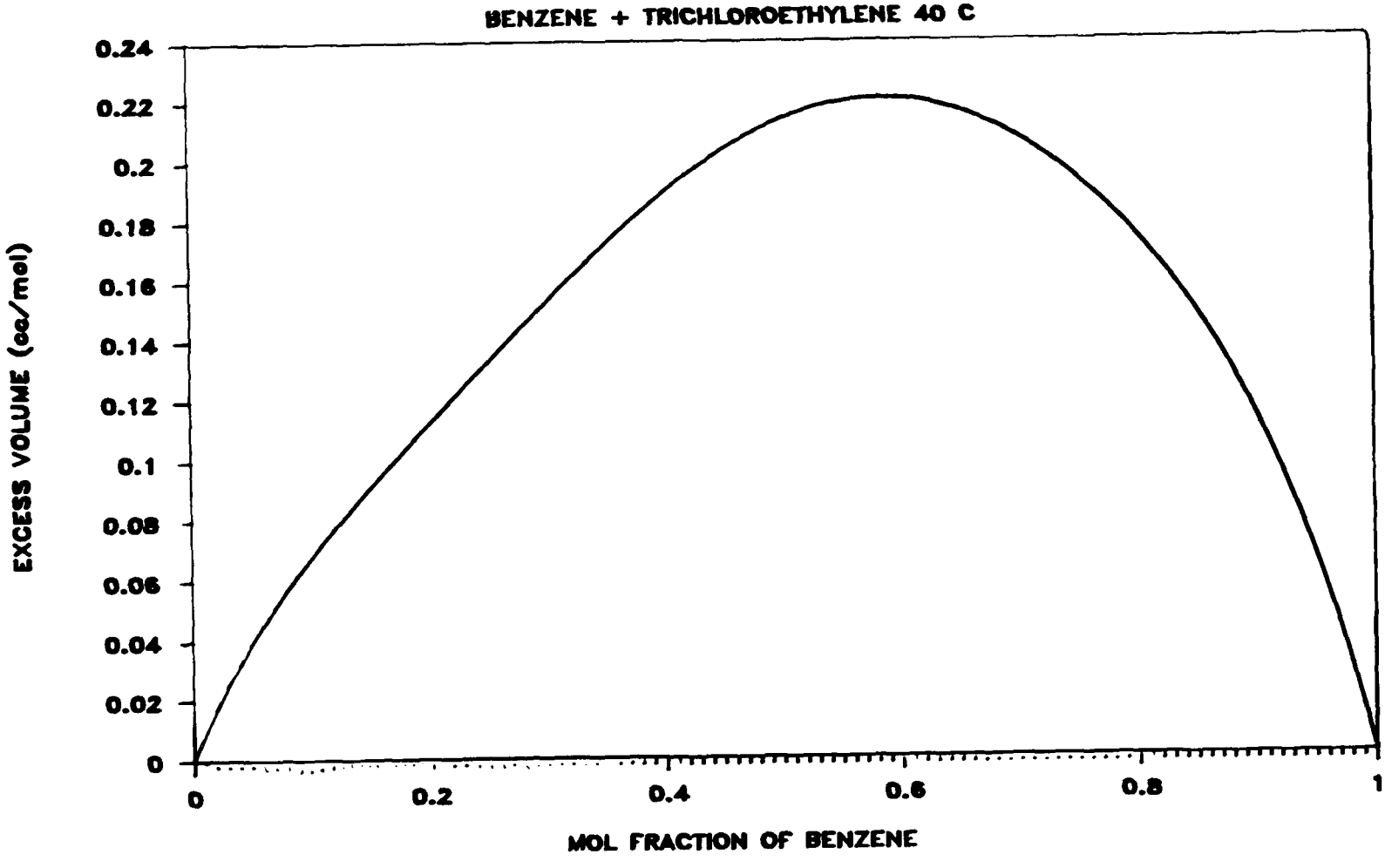

BENZENE + TRICHLOROETHYLENE 40 C
EXCESS VOLUME (cc/mol)
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

FIGURE 14

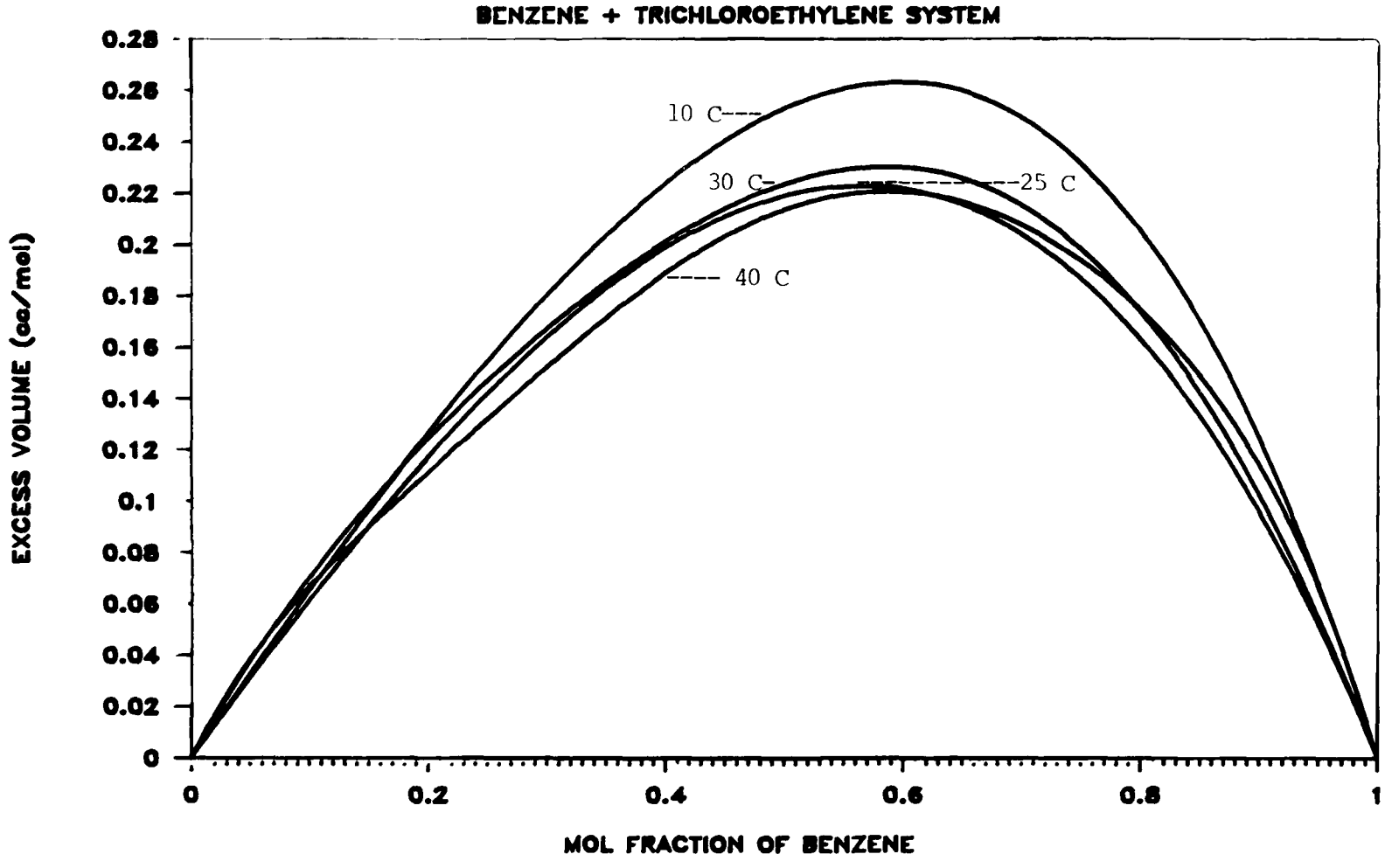

BENZENE + TRICHLOROETHYLENE SYSTEM
EXCESS VOLUME (cc/mol)
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
10 C
30 C
25 C
40 C
0
0.2
0.4
0.6
0.8
1
MOL FRACTION OF BENZENE

TABLE 2

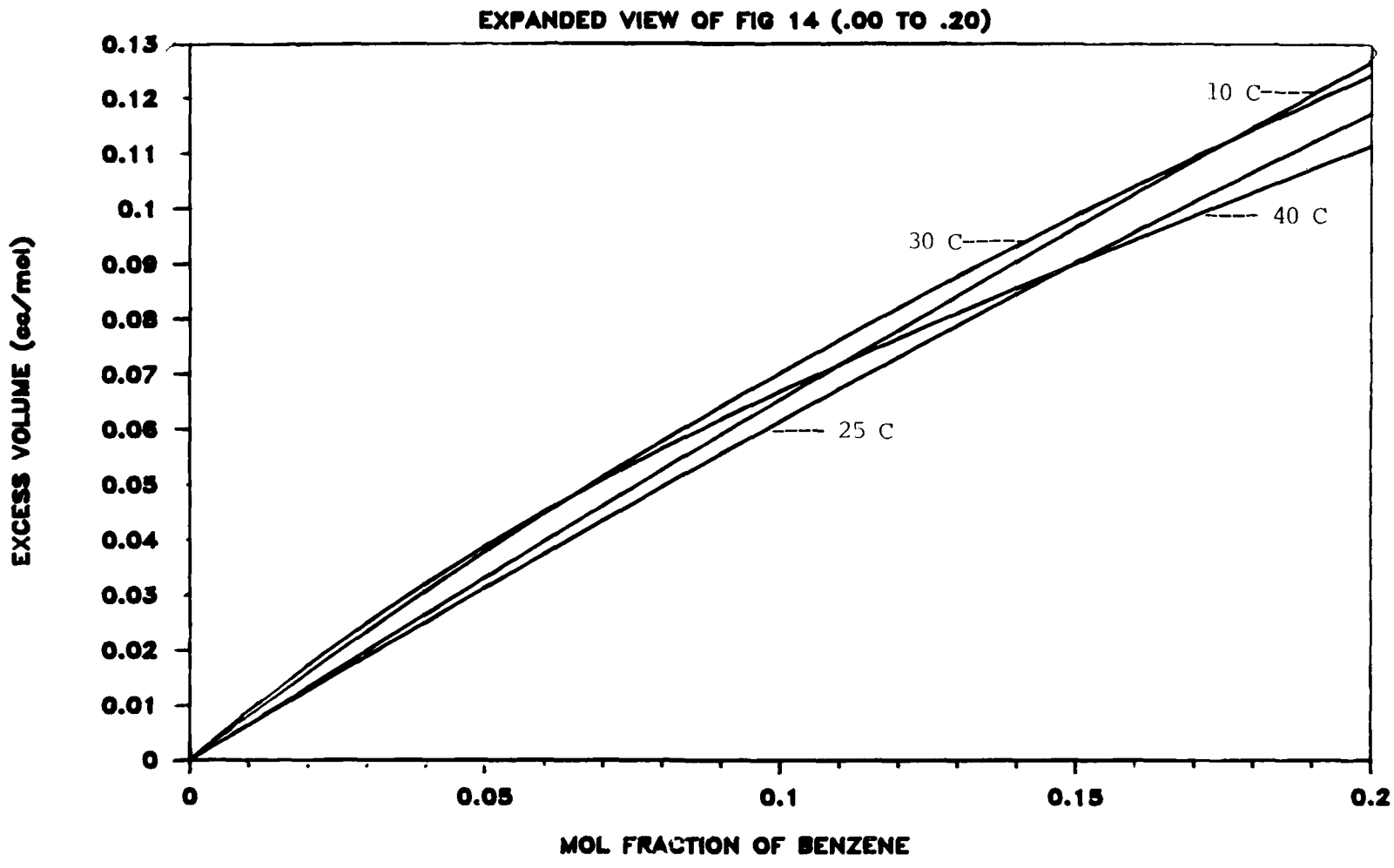
CURVE FITTING DATA FOR THE
BENZENE + TRICHLOROETHYLENE SYSTEM

Temp (^{o}C)	a_o	a_1	a_2	a_3	a_4	std. dev (cc/mol)
10	1.01164	-.41103	.07189	0	0	.00801
25	.87624	-.23889	0	0	0	.00825
30	.89426	-.30734	.10541	.13159	0	.00324
40	.85454	-.33061	-.05882	.00471	.46645	.00409

The maximum point, which occurs between .565 and .597 on all four of these curves is in sufficient agreement to say that there is no tendancy for the data to skew one way or the other with increasing temperature. It should also be noted that over the majority of the mole fraction range, the molar excess volume of the system decreases with increasing temperature. Although all four of the curves are relatively uniform in curvature, increasingly more curve fitting constants were generally required to accurately describe the system as the temperature increased.

Below .20, and again above .60 mole fraction of benzene, an inversion in the relationship of mole fraction to excess volume was observed to occur. Figures 15 and 16 are expanded views of Figure 14 below .20 and above .60 mole fraction of benzene, respectively. The explanation of this phenomenon is beyond the scope of this investigation, but highlights the complex nature of the forces involved in this system.

FIGURE 15


EXPANDED VIEW OF FIG 14 (.00 TO .20)
EXCESS VOLUME (cc/mol)
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.05
0.1
0.15
0.2
MOL FRACTION OF BENZENE
10 C
30 C
40 C
25 C

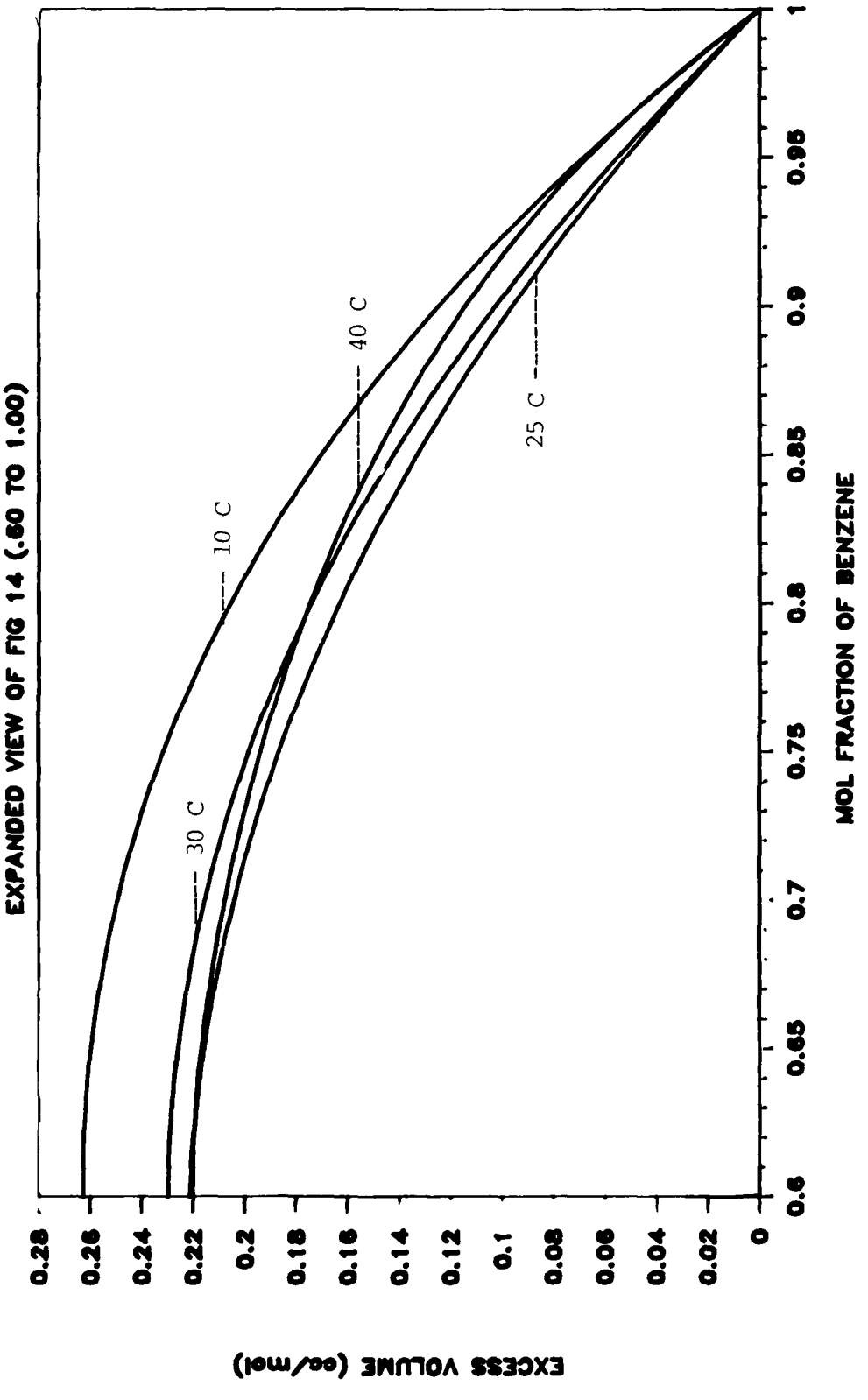


FIGURE 16
EXPANDED VIEW OF FIG 14 (.60 TO 1.00)
EXCESS VOLUME (cc/mol)
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
MOL FRACTION OF BENZENE
10 C
30 C
40 C
25 C

All four of these data sets have reasonable standard deviations, but the 10 and 25 ^{o}C sets had notably higher standard deviations than those for the 30 and 40 ^{o}C sets. See Appendix C-2 for specific information about standard deviations, data point error, and condition numbers for each temperature in this system. Finally, the data appear to be sufficiently good for information at other temperatures between 10 and 40 ^{o}C to be interpolated with reasonable accuracy. An empirical equation relating the height of the excess volume peak to the temperature of the system is:

$$V_{eT} = -.00140 * T + .653697$$

Where the units of V_{eT} are cc/mol and T is in K. This equation was derived from a linear regression of the peak values for the four temperatures.

CHAPTER VI

CONCLUSIONS

1. The data for the benzene + cyclohexane system compare well with other experimenters in terms of standard deviation, maximum value, and general shape of the curve, but is slightly low in the location of the maximum point on the x axis, although it is within the range of acceptibility.
2. The data presented for the benzene + trichloroethylene system are as good as the data for the benzene + cyclohexane system, have standard deviations that are within acceptible limits, have peak values near 58 percent benzene, and can be used to interpolate data at other temperatures.
3. For the benzene + trichloroethylene system, as the temperature increases, the number of fitting constants required to describe the curve generally increases.
4. For the majority of the benzene + trichloroethylene system, the excess volume of mixing decreases with increasing temperature, although an inversion of this relationship takes place near both ends of the excess volume versus mole fraction curve.
5. As more data points are taken to describe a given system, the standard deviation and the L_1 condition decrease.

6. The inaccuracy of reading the temperature from an uncalibrated thermometer had no effect on the internal consistency of the data. This implies that the temperature bath was controlled to a degree of precision better than any of the thermometers were capable of reading.
7. With an increase in the precision of the cathetometer that measures the buret data, an increase of precision in the excess volume data and the standard deviations would follow. The excess volume precision would likely increase decimal point for decimal point with the precision increase of the cathetometer, with modifications made for ill conditioning if too few data points are collected.
8. The curve fitting constants and standard deviations for each of the benzene + trichloroethylene systems are as noted in Table 2.

CHAPTER VII

RECOMMENDATIONS

1. Obtain a second high precision cathetometer to measure the height data on the buret.
2. Obtain NBS calibrated thermometers to cover a wide range of temperatures, perhaps at ten degree increments from 0 to 100 ^{o}C, to accurately set the temperature bath at the desired set point.
3. Take as many data points as possible in further investigations to lower the population standard deviation and to keep the ill conditioning of the coefficient matrix from negating the positive effects gained from the use of higher precision equipment.
4. Continue the study of the benzene + trichloroethylene system at extreme temperatures, such as -10, 0 and 60 ^{o}C, to see if the observed trends continue to manifest themselves.
5. Obtain and calibrate a spare set of capillaries and burets for use in case of accidental breakage.

APPENDIX A

DETAILED PROCEDURES

APPENDIX A-1

BURET CALIBRATION

Buret Calibration

1. Clean the dilatometer.
2. Fill a syringe to a reasonable level with clean mercury, less than half full is acceptable. The rationale for this amount is that if the weighing will be done in an enclosed scale, the entire syringe (needle, body, and plunger) must fit within the confines of the scale when the scale doors are shut. Never attempt to over fill the syringe and attempt to get an accurate weight with the scale doors open because the room air currents are sufficient to cause errors in the weight.
3. Weigh the syringe and record this weight.
4. Tilt the dilatometer such that the buret is inclined slightly above horizontal. Slowly inject the mercury into the buret while keeping the opening of the needle flat against the side of the buret. The mercury drops should slowly run down the wall of the buret and pool up at the bottom.
5. When all mercury possible has been injected into the buret, withdraw the syringe and reweigh it. Care must be taken to ensure that no mercury remaining in the syringe is allowed to escape. Record this weight.
6. Repeat steps 2 - 5 as many times as needed to ensure the mercury level in the buret is above the reference mark at the lower end of the buret. Better results can be

achieved if the level is as close to the reference line as possible, as long as it is above it.

7. Visually inspect the mercury in the buret to ensure that no air bubbles are visible. If a bubble is detected, tilt the dilatometer in a manner such that the trapped air bubble(s) may rejoin the air above the mercury.
8. Replace the tap on the buret and tighten it. For calibration of the buret only, the tap with the level bubble should be used on the buret and the plain tap on the mixing bowl.
9. Place the dilatometer in the stand and place the stand in the temperature bath. Insert the cooling unit temperature sensor into the bath through a hole in the top of the stand.
10. Level the dilatometer by using the level bubble and making appropriate corrections with the height adjustment rods.
11. Allow the system to reach thermal equilibrium at the desired operating temperature, which should be held constant throughout the calibration.
12. Read the height to the reference line and the height to the meniscus using a cathetometer. Record these readings.
13. Fill a syringe with a small alloquit of mercury. The smaller the amount, the better the calibration will be. One-half cc works well.
14. Remove the temperature sensor from the bath and

withdraw the stand. Take the dilatometer out of the stand and open the tap on the buret, being careful to exclude the entrance of any water into the buret.

15. Weigh the mercury addition and add it to the buret as in steps 3 - 5.
16. Reassemble the apparatus and allow it to reach thermal equilibrium as in steps 7 - 11.
17. Measure the height to the reference line and to the meniscus as in step 12. Note: Whenever the dilatometer is moved, the reference line must be remeasured.
18. Repeat steps 13 - 17 until the range of the cathetometer is exceeded or the desired height of the buret has been calibrated.
19. When a calibration run has been completed, calculate the cross-sectional area for each addition.
20. Mathematically analyze the data for the mean cross-sectional area, the population standard deviation, and the sample standard deviation. For a calibration run to be successful, the standard deviation values must be regarded as "good" by some standard. For two or more runs to be consistant, the standard devaitions and the means should all be in "reasonable" agreement.

APPENDIX A-2

DILATOMETER CLEANING PROCEDURES

Dilatometer Cleaning Procedures

1. The dilatometer should be cleaned prior to each loading.
2. Pour nitric acid into the buret in sufficient quantities to fill the buret and the mixing bowl. A funnel with a short stem should be used.
3. Tilt the dilatometer back and forth in such a manner that the nitric acid comes in contact with all of the inner surface of the dilatometer, to include the capillaries.
4. Pour out the nitric acid and fill as much of the dilatometer as possible with distilled water.
5. Rinse the dilatometer as in step 3, then pour out water.
6. Add ethyl alcohol to the dilatometer as in step 2, then rinse as in step 3 and pour out the alcohol.
7. Execute step 6 again with acetone instead of alcohol.
8. When the acetone has been poured out, connect a vacuum pump to capillary C. Allow the vacuum to operate until tubes S1 and S2 as well as taps T1 and T2 are dry.
9. Turn off the vacuum and insert both taps tightly. Then turn the vacuum back on and let it operate until the dilatometer is completely dry on the inside.

Note: It is helpful to conduct the vacuum operation with the dilatometer in an inverted position. This prevents acetone from collecting in the bulb at the bottom of the buret and speeds the drying process considerably.

APPENDIX A-3

DILATOMETER LOADING PROCEDURES

Dilatometer Loading Procedures

Refer to Figure 4 for the nomenclature used in this section.

1. First, clean the dilatometer.
2. Inject mercury into the mixing bowl through tap T2 with a long needle and a small tube attached to a syringe. Care should be taken to keep the tube opening just above the level of the mercury to ensure that no air bubbles become entrapped in the mercury pool.
3. As the horizontal tube fills with mercury, inspect periodically for the formation of air bubbles. If any bubbles form, tilt the dilatometer appropriately to allow the air bubble(s) to escape.
4. Continue to fill the mixing bowl with mercury until about two thirds of the upper hemispherical portion of the bowl are full.
5. Put both taps in place, but do not fully seat them. Allow T2 to be open enough so that mercury can be injected through S2 into the mixing bowl.
6. Place the dilatometer in its stand and lower it into the temperature bath which is set at the run operating temperature.
7. When thermal equilibrium has been reached, remove the dilatometer from the temperature bath and inject just enough mercury into the mixing bowl through S2 so that, when tap T2 is closed, no air will be trapped inside,

but not enough so that there is an overflow of mercury into S2 or a pressurizing effect when T2 is closed.

8. Close T2 and place the dilatometer back in the temperature bath.
9. Again, allow for thermal equilibrium to be reached, then measure the heights of the mercury columns in C, C1, and C2 with respect to CR.
10. When it is desired to operate the dilatometer near or above the ambient temperature, both the solvent and the solute should be degassed prior to loading them into the dilatometer. This can be most conveniently accomplished by bringing each component to boiling just prior to injecting it into the dilatometer.
11. Remove the dilatometer from the bath and open both taps, being careful not to allow any water to enter the dilatometer. Inject the solute component into the buret. This is accomplished with the help of a long needle and a syringe. Fill the buret with this component by placing the opening of the needle against the side of the buret and slowly injecting the solute in such a manner that it flows down the walls of the buret in a film.
12. Continue to fill the buret until the level of the solute is above the upper openings of both C1 and C2.
13. Momentarily, tilt the dilatometer toward the buret such that mercury drops flow from both C1 and C2. When the air trapped inside C2 has escaped into the buret, tilt

the buret upright again.

14. Tilt the dilatometer in such a manner that mercury flows into the buret only from C1. Allow mercury to flow from C1 into the buret until the bulb at the bottom is full of mercury and the meniscus of the mercury is slightly above reference line BR.
15. As mercury falls into the buret, the solute level will rise. The excess solute should be removed with a syringe through tap T1 from time to time.
16. Once this portion of the procedure is complete, ensure the solute level is even with the lower opening of S1.
17. Replace tap T1, but leave it slightly vented to S1.
18. Fill the vacant space in the mixing bowl with the solvent as in step 2. Bring the level of the solvent even with the lower opening of S2.
19. Replace tap T2, but leave it slightly vented to S2.
20. Place the dilatometer back into its stand and lower it into the temperature bath.
21. When thermal equilibrium has been reached, seal both taps and measure the heights of mercury in columns C, C1, C2, and the mixing bowl with respect to CR and the height of mercury in the buret with respect to BR.
22. If any of the capillary readings cannot be made conveniently, their levels may be adjusted in the following manner. Remove the dilatometer from the temperature bath. Open tap T1 partially, and either allow more solute into the buret or remove a few drops, as

required, by tilting the dilatometer appropriately. Place the dilatometer back in the temperature bath and execute step 21 again. By iterating through steps 21 and 22, acceptable mercury levels can be obtained in all three capillareis.

APPENDIX A-4

TEMPERATURE CONTROL

Temperature Control

These procedures were designed for use with the TCV-70 Tamson thermostatic bath and the PBC-2 II Neslab portable bath cooler with a Cryotrol temperature controller.

1. The bath should be filled with a suitable heat transfer medium before beginning a run, as prescribed in the operating manual. For most applications, distilled water is sufficient.
2. Cooling is usually required only when the desired run temperature is less than 8 degrees above the ambient temperature.
3. If cooling is required, the cooler should be set for minimum cooling duty and the Cryotrol temperature controller should be set at a temperature close to, but below the desired operating temperature. This permits the more accurate temperature controller on the thermostatic bath to control the bath temperature.
4. The heating capacity on the temperature bath should be set to the lowest possible value. This setting is experimentally determined in the following manner:
   a. Turn the bath and the cooler (if appropriate) on and ensure the temperature of the water in the bath is below the desired operating temperature.
   b. Set the temperature control on the bath to the desired temperature.

c. Set the heating capacity knob to its lowest value.

d. Allow the bath to operate and observe the temperature.

e. Adjust the heating capacity upwards until the temperature in the bath begins to climb.

f. Verify that the bath can reach the desired operating temperature by adjusting the set point upwards so that the bath temperature climbs above the desired operating temperature. If the temperature quits climbing before the operating temperature is exceeded, continue adjusting the heating capacity upwards until this goal is achieved.

5. Set the temperature controller on the bath lower than the desired operating temperature and allow the bath to stabilize there.

6. Adjust the temperature controller very slightly upwards and again allow the bath to stabilize in temperature.

7. Repeat the procedure in step 6 until the operating temperature is reached.

8. The temperature controls are now set for a run and should not need adjusting unless ambient conditions change significantly.

9. At the end of each day of operation, refill the temperature bath with distilled water.

10. Let the bath run continuously during a run to prevent instability and to facilitate the next day's operation.

APPENDIX A-5

OPERATING PROCEDURES

Operating Procedures

Before beginning, choose an operating temperature and set-up the temperature bath appropriately. Also, choose the two component system to be investigated.

1. Designate one component as the solute and the other as the solvent.
2. Clean and load the dilatometer, recording the appropriate data as described in the loading procedures.
3. Remove the dilatometer from the bath.
4. With the buret on the right, tilt the dilatometer in a clockwise direction, allowing a few drops of mercury to spill into the buret from capillary C1. Right the dilatometer and place it back in the temperature bath.

Note: After the tilt, inspect capillary C2 to ensure that there is no separation in the mercury column. If this should occur, immediately retilt the dilatometer. An abrupt tilt reduces the risk of mercury separation.

5. Allow the system to reach thermal equilibrium. This takes about 30 minutes, and can be visually determined by observing the mercury in capillary C. When this mercury level reaches a stationary location, thermal equilibrium has been reached.
6. Connect capillary C to the back pressure device and turn the stopcock to the vent position.
7. Read and record the levels of mercury in capillaries C,

C1, and C2; the mixing bowl; and the buret. Also, record the level of reference marks CR and BR.

8. Turn the stopcock to the closed position and put a back pressure of about 24 cm on the system as determined by observing the change in height of the mercury in the U tube.
9. Record the net change of height of mercury in the U tube, ensuring that any initial differential in mercury column heights is accounted for.
10. Record the change in height of mercury in capillary C.
11. For the first few tilts, only a few drops of mercury should be allowed to spill into the buret. This facilitates a more accurate determination of infinite dilution values.
12. After the first few tilts, gradually increasing amounts of mercury may be spilled into the buret until, eventually, the change in mercury height in the buret is about 1 cm per tilt. Once this value is reached, the run should be finished out at about 1 cm of mercury change in the buret per tilt.
13. This procedure should continue until the mercury in the buret reaches the point where the buret cross-sectional area begins to vary as it merges with the horizontal tube.
14. Repeat steps 1 - 13 with the solute and solvent roles reversed. This procedure should yeild two curves that merge at the center with a significant overlap.

APPENDIX B

EXPERIMENTAL DATA

NOMENCLATURE FOR APPENDIX B

A	Mixing bowl on the dilatometer
B	Buret on the dilatometer
BR	Reference mark on the buret
C, C1, C2	Capillary tubes on the dilatometer
CR	Reference mark on capillary C
del C pi	Pressure corrected change in height of mercury in C
del U	Back-pressure applied to C

TABLE 3

EXPERIMENTAL DATA FOR DILUTION RUN #2

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	0.0847	3.9908		4.1064	4.0714				
INITIAL	0.0853	2.1622	1.6787	-0.6320	-0.5710	5.65	6.02		
1	0.0929	2.4424	1.6417	1.5323	2.0239	5.62	6.16	-0.1150	24.60
2	0.0849	2.5811	1.6069	1.9475	2.2647	5.63	6.30	-0.1351	24.10
3	0.0574	2.6611	1.6451	2.3716	2.4124	5.64	6.40	-0.1475	28.10
4	0.0868	2.8200	1.6086	3.1676	3.2854	5.60	6.48	-0.1405	24.25
5	0.0539	2.9256	1.5905	4.0520	4.0189	5.60	6.54	-0.1330	24.45
6	0.0964	3.0678	1.5874	4.6886	4.7367	5.60	6.66	-0.1149	24.55
7	0.0956	3.4289	1.5746	2.5891	3.2255	6.03	7.57	-0.0919	25.10
8	0.0583	3.9319	1.5233	1.8327	1.8949	6.03	8.23	-0.1106	24.05
9	0.0292	4.3234	1.4749	1.4297	1.6792	6.04	8.77	-0.1192	24.35
10	0.0858	4.4922	1.4889	1.4039	1.7722	6.03	8.92	-0.1113	24.20
11	0.0642	4.6917	1.4527	2.2232	2.3119	6.25	9.37	-0.1155	24.00
12	0.0997	5.1164	1.4405	1.5456	1.9350	6.23	9.91	-0.1044	24.00
13	0.0978	5.1758	1.4339	1.6766	1.7905	6.23	10.04	-0.1239	24.60
14	0.1018	5.4009	1.4196	2.6918	2.7344	6.25	10.30	-0.1387	24.70
15	0.1011	5.7066	1.4017	1.5738	1.7004	6.25	10.94	-0.0782	23.50
16	0.0999	5.8441	1.3991	1.6303	1.7311	6.27	11.13	-0.1257	24.50
17	0.0825	6.3108	1.3522	1.5864	1.6953	6.27	11.82	-0.1287	24.20
18	0.1049	6.4954	1.3395	1.5934	1.6759	6.25	12.12	-0.1189	24.40
19	0.0908	6.7022	1.3114	1.6900	1.7680	6.23	12.47	-0.1067	24.60
20	0.1087	6.8938	1.3002	1.7585	1.8479	6.26	12.79	-0.1110	23.90
21	0.0690	6.9527	1.2864	1.6345	1.6911	6.27	12.99	-0.1131	24.40
22	0.0978	7.2244	1.2647	1.4782	1.5129	6.25	13.46	-0.1074	24.30
23	0.0807	7.3924	1.2202	1.5363	1.5914	6.24	13.84	-0.1472	23.70
24	0.0890	7.4739	1.1958	1.6157	1.6548	6.24	14.08	-0.1041	24.00
25	0.0986	7.8097	1.1577	1.6737	1.6542	6.24	14.78	-0.0897	24.10
26	0.1241	7.9567	1.1905	1.6544	1.7310	6.23	15.00	-0.1039	24.20
27	0.0955	7.9793	1.1630	1.7841	1.8399	6.25	15.14	-0.1342	24.55
28	0.0916	8.0678	1.1384	1.6776	1.7510	6.28	15.36	-0.1262	24.00
29	0.0873	8.1169	1.1037	1.7201	1.7903	6.25	15.45	-0.1049	24.00
30	0.1018	8.3249	1.0884	1.6237	1.6440	6.24	15.92	-0.1299	24.45
31	0.0767	8.4124	1.0749	1.6817	1.6799	6.28	16.19	-0.1157	24.35
32	0.1110	8.5429	1.0719	1.7884	1.7992	6.28	16.50	-0.1013	24.00
33	0.1208	8.6564	1.0822	1.5804	1.5775	6.29	16.78	-0.1035	24.60
34	0.1287	8.8043	1.0690	1.7869	1.7947	6.29	17.07	-0.1187	25.05

TABLE 3

EXPERIMENTAL DATA FOR DILUTION RUN #2 (CONTINUED)

TILT #	CR	C	A	C2	C1	Bk	B	del C pi	del U
35	0.0111	8.8017	0.9291	1.5781	1.6350	6.27	17.38	-0.1260	24.15
36	-0.0041	8.8816	0.9069	1.5220	1.5519	6.27	17.64	-0.1234	24.25
37	-0.0210	8.9679	0.8801	1.6929	1.7061	6.25	17.87	-0.0998	23.90
38	0.0445	9.1724	0.8814	1.5060	1.6354	6.24	18.30	-0.1185	24.25
39	-0.0128	9.2281	0.8562	1.6507	1.6653	6.28	18.62	-0.1167	24.05
40	0.0028	9.3814	0.8345	1.6385	1.3649	6.27	19.02	-0.1234	23.70
41	-0.0377	9.4355	0.7782	1.6406	1.6457	6.24	19.26	-0.1074	23.85
42	-0.0052	9.5919	0.7593	1.6554	1.6781	6.26	19.66	-0.0841	24.40
43	-0.0100	9.7086	0.7240	1.5895	1.5976	6.28	20.00	-0.1257	24.20
44	-0.0010	9.9765	0.7117	1.4239	1.4403	6.27	20.89	-0.1140	24.25
45	0.0208	10.1045	0.6756	1.6149	1.6071	6.31	21.31	-0.1009	24.40
46	0.0071	10.2579	0.6707	1.4632	1.4734	6.31	21.91	-0.1117	24.50
47	-0.0036	10.3924	0.6224	1.6235	1.6108	6.29	22.45	-0.0853	24.15
48	-0.2967	10.2055	0.3230	1.1757	1.1673	6.27	22.85	-0.1064	24.15
49	-0.2723	10.3894	0.3089	1.4249	1.4293	6.27	23.31	-0.0769	23.65
50	-0.4540	10.3476	0.1500	1.2287	1.2148	6.31	23.81	-0.0921	24.15

TABLE 4

EXPERIMENTAL DATA FOR DILUTION RUN #3

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	0.0465	5.7926		5.6246	5.6825				
INITIAL	0.1012	1.0252	1.7170	-0.3385	-0.3298	6.34	6.6		
1	0.0613	1.2406	1.6858	1.4343	1.4417	6.33	6.69	-0.1086	24.10
2	0.1011	1.4965	1.6849	1.6402	1.6539	6.35	6.91	-0.0609	24.40
3	0.0815	1.6857	1.6655	1.6391	1.6538	6.37	7.08	-0.1017	23.80
4	0.0802	2.0073	1.6470	1.6107	1.6336	6.32	7.33	-0.0795	23.65
5	0.0732	2.2234	1.6256	1.5959	1.6082	6.32	7.49	-0.1051	23.80
6	0.1342	2.5413	1.6668	1.5935	1.6019	6.02	7.41	-0.1130	24.60
7	0.0983	2.6969	1.6288	1.6712	1.6805	6.01	7.60	-0.0905	24.20
8	0.1084	2.8577	1.6144	1.5918	1.6077	6.00	7.73	-0.0884	24.25
9	0.1161	2.9949	1.6735	1.6914	1.7023	6.00	7.88	-0.0901	23.95
10	0.0993	3.2550	1.5946	1.6898	1.6955	6.00	8.14	-0.0898	24.00
11	0.0969	3.4321	1.5671	1.7357	1.7484	6.00	8.31	-0.1115	23.95
12	0.1239	3.5570	1.5973	1.7976	1.8004	6.01	8.45	-0.0940	24.50
13	0.1035	3.6941	1.5822	1.6754	1.6754	6.01	8.63	-0.0829	23.90
14	0.1319	3.9884	1.5917	1.4504	1.4622	6.02	8.99	-0.0911	24.00
15	0.1410	4.1807	1.5706	1.6960	1.7095	6.02	9.20	-0.0932	23.90
16	0.1518	4.2925	1.5757	1.5984	1.6280	6.05	9.34	-0.1144	23.90
17	0.0863	4.3600	1.5140	1.6362	1.6578	6.00	9.49	-0.0939	24.35
18	0.0883	4.4849	1.5035	1.6330	1.6427	6.00	9.65	-0.1046	24.30
19	0.0966	4.6226	1.4999	1.5642	1.5900	6.02	9.85	-0.0982	24.20
20	0.1268	4.8196	1.5034	1.7475	1.7562	6.02	10.07	-0.0979	24.25
21	0.1296	4.8885	1.4964	1.7897	1.7942	6.02	10.23	-0.1007	24.60
22	0.1091	5.0118	1.4807	1.6418	1.6734	6.01	10.41	-0.1059	23.85
23	0.1302	5.1423	1.4895	1.7019	1.7047	6.02	10.62	-0.1009	24.00
24	0.1355	5.2534	1.4595	1.6142	1.6446	6.03	10.83	-0.0849	24.10
25	0.1250	5.3653	1.4533	1.6891	1.6963	6.02	11.00	-0.0933	24.00
26	0.1305	5.4841	1.4387	1.6375	1.6450	6.03	11.20	-0.0913	24.30
27	0.1109	5.5502	1.4199	1.6008	1.5936	6.02	11.33	-0.0985	24.60
28	0.1180	5.6495	1.4061	1.6308	1.6320	6.01	11.52	-0.0837	24.30
29	0.1135	5.7404	1.4004	1.5616	1.5628	6.01	11.64	-0.1070	23.60
30	0.1128	5.8221	1.3868	1.5113	1.5184	6.03	11.87	-0.0907	24.15
31	0.2075	5.9734	1.4673	1.7336	1.7418	6.07	12.11	-0.1083	24.00
32	0.1419	6.1176	1.3940	1.5375	1.5829	6.05	12.50	-0.0978	23.90
33	0.1337	6.2221	1.3679	1.5749	1.5988	6.06	12.69	-0.1106	24.25
34	0.1202	6.2855	1.3452	1.6269	1.6490	6.03	12.81	-0.1103	24.20

TABLE 4

EXPERIMENTAL DATA FOR DILUTION RUN #3 (CONTINUED)

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
35	0.1152	6.4446	1.3280	1.7243	1.7319	6.02	13.02	-0.1285	24.45
36	0.1036	6.5240	1.3106	1.5866	1.6170	6.01	13.24	-0.0989	24.05
37	0.1477	6.6514	1.3225	1.6861	1.7287	6.03	13.49	-0.1009	24.25
38	0.1386	6.7113	1.3091	1.7172	1.7428	6.02	13.67	-0.0999	24.10
39	0.1434	6.8242	1.2949	1.5788	1.6004	6.03	13.92	-0.1005	24.40
40	0.1483	6.9203	1.2783	1.6130	1.6169	6.03	14.14	-0.1003	23.95
41	0.1300	6.9929	1.2613	1.6941	1.6972	6.02	14.34	-0.1135	24.15
42	0.1454	7.1073	1.2418	1.7550	1.7574	6.02	14.66	-0.0939	24.30
43	0.1289	7.1624	1.2349	1.7346	1.7287	6.02	14.82	-0.1046	24.15
44	0.1345	7.2512	1.2194	1.7534	1.7560	6.00	15.05	-0.1099	24.10
45	0.1038	7.3105	1.1786	1.7142	1.7657	6.01	15.26	-0.1009	24.30
46	0.1421	7.4199	1.2037	1.7275	1.7360	6.01	15.51	-0.1069	23.75
47	0.1207	7.4468	1.1744	1.5982	1.6067	6.00	15.67	-0.0925	23.95
48	0.2080	7.6339	1.2379	1.7465	1.7493	6.09	15.97	-0.1094	23.75
49	0.1365	7.6432	1.1628	1.6229	1.6328	6.03	16.20	-0.1184	24.30
50	0.0991	7.6843	1.1081	1.6410	1.6527	6.00	16.38	-0.1224	24.10
51	0.1444	7.8101	1.1308	1.6632	1.6713	6.02	16.78	-0.0816	24.20
52	0.1949	7.9521	1.1597	1.7723	1.7883	6.08	17.07	-0.1193	23.80
53	0.1014	7.9397	1.0749	1.6586	1.6676	6.01	17.27	-0.1123	24.05
54	0.1480	8.0525	1.0771	1.6803	1.6787	6.00	17.52	-0.1125	23.80
55	0.2980	8.2846	1.2165	1.8564	1.8590	6.19	18.03	-0.0996	23.75
56	0.1279	8.1918	1.0487	1.6590	1.6668	6.02	18.12	-0.1048	24.30

TABLE 5

EXPERIMENTAL DATA FOR DILUTION RUN #4

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	0.0029	6.1049		5.8614	5.9315				
INITIAL	0.7611	7.0111	2.7203	-0.5069	-0.4603	5.11	5.33		
1	-0.0240	6.4267	1.9264	1.7892	1.7628	5.13	5.37	-0.0010	23.80
2	-0.0179	6.6011	1.9297	2.1351	2.1477	5.14	5.47	-0.0990	23.80
3	-0.0331	6.6422	1.8988	2.0996	2.1012	5.15	5.62	-0.1040	23.60
4	-0.0127	6.7676	1.8585	1.4230	1.4316	5.16	5.87	-0.0806	24.45
5	-0.0350	7.0215	1.8184	0.7775	1.1505	4.97	6.19	-0.1055	23.70
6	-0.0383	7.1151	1.7988	1.5576	1.8522	4.94	6.44	-0.0904	23.90
7	-0.0018	7.2504	1.8600	1.3643	1.5675	4.98	6.67	-0.1238	24.25
8	-0.0682	7.2570	1.7962	2.1513	2.1778	4.94	6.73	-0.1147	24.95
9	-0.0904	7.3055	1.7519	1.6567	1.6673	4.95	6.94	-0.1026	23.65
10	-0.0171	7.4624	1.7652	1.4818	1.9650	4.97	7.19	-0.0803	23.80
11	-0.0557	7.4743	1.7369	2.1383	2.1328	4.93	7.28	-0.1311	24.70
12	-0.0114	7.7047	1.7246	1.0917	1.5597	4.95	7.83	-0.0948	24.35
13	-0.0293	7.7827	1.7526	1.6417	1.9064	4.98	8.00	-0.1262	24.30
14	-0.0349	7.8216	1.7120	1.6155	1.7924	4.97	8.22	-0.0928	24.90
15	-0.0270	7.9233	1.6937	1.4902	1.7550	4.96	8.49	-0.1153	24.00
16	-0.0607	7.9903	1.6404	1.1939	1.5720	4.92	8.88	-0.2322	24.10
17	-0.0306	8.0931	1.6723	1.4775	1.7420	4.98	9.02	-0.1341	23.75
18	-0.0112	8.0840	1.6853	1.6546	1.8968	4.97	9.16	-0.0851	23.45
19	-0.0195	8.1107	1.6528	1.3730	1.8300	4.98	9.47	-0.0878	23.65
20	-0.0491	8.1525	1.6105	1.6382	1.6300	4.98	9.82	-0.1562	23.80
21	-0.0616	8.1517	1.5850	1.4880	1.5748	4.97	10.16	-0.0871	23.60
22	-0.0335	8.3427	1.5699	1.0732	1.4212	4.95	10.80	-0.1022	23.80
23	-0.0222	8.4264	1.5410	1.4334	1.6117	4.97	11.23	-0.0999	23.85
24	-0.0207	8.5203	1.5295	1.5575	1.8857	4.98	11.55	-0.1082	23.50
25	-0.0368	8.5533	1.5076	1.6271	1.8069	4.97	11.93	-0.1029	23.90
26	-0.0264	8.6312	1.4937	1.6016	1.7364	4.98	12.31	-0.0825	23.80
27	-0.0533	8.6489	1.4390	1.7250	1.8630	4.93	12.76	-0.0755	24.10
28	-0.0505	8.7362	1.4291	1.7189	1.8297	4.96	13.08	-0.0932	23.95
29	-0.1251	8.6474	1.3314	1.5658	1.6294	4.99	13.41	-0.1251	24.05
30	-0.1277	8.6611	1.2868	1.5622	1.7852	4.97	13.73	-0.1194	24.00
31	-0.1167	8.6905	1.2694	1.8009	1.8357	4.95	14.18	-0.1243	24.05
32	-0.0867	8.7703	1.2632	1.6107	1.6129	4.96	14.54	-0.0858	23.90
33	-0.4090	8.5024	1.0395	1.6567	1.6424	4.87	15.00	-0.0835	23.75
34	-0.3562	8.6065	1.0214	1.5077	1.6944	4.86	15.47	-0.0727	24.10

TABLE 5

EXPERIMENTAL DATA FOR DILUTION RUN #4 (CONTINUED)

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
35	-0.3576	8.6974	1.0293	1.5829	1.7733	4.87	15.91	-0.1337	23.65
36	-0.4001	8.6782	0.9775	1.5601	1.6554	4.88	16.48	-0.1140	24.15
37	-0.4008	8.7376	0.9071	1.3420	1.5768	4.88	17.40	-0.1035	23.65
38	-0.4159	8.7779	0.8776	1.5555	1.8098	4.87	17.92	-0.1147	24.15
39	-0.4712	8.7381	0.7825	1.6857	1.8314	4.90	18.61	-0.0953	23.85
40	-0.4577	8.7917	0.7514	1.7367	1.7303	4.91	19.16	-0.0983	23.60
41	-0.5780	8.6815	0.6002	1.6020	1.6816	4.92	19.88	-0.0731	24.20
42	-0.5746	8.7113	0.5937	1.4483	1.6461	4.95	20.70	-0.0390	23.75
43	-0.5804	8.8193	0.5588	1.6833	1.8232	4.92	21.57	-0.1272	23.85

TABLE 6

EXPERIMENTAL DATA FOR DILUTION RUN #5

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	-0.0946	5.0459		4.7473	4.7321				
INITIAL	-0.1582	-0.2274	1.8029	-0.1739	-0.0900	5.07	5.26		
1	-0.2363	-0.2910	1.7667	1.8576	1.9383	5.03	5.29	-0.0742	23.95
2	-0.1903	-0.1751	1.7612	1.7848	1.8380	5.05	5.64	-0.0905	23.95
3	-0.1763	0.0040	1.7748	1.8059	1.9294	5.05	5.88	-0.0955	23.75
4	-0.1696	0.0741	1.7767	1.8963	1.9270	5.03	6.19	-0.0863	24.10
5	-0.1571	0.1507	1.7463	1.8177	1.8598	5.05	6.53	-0.1196	24.25
6	-0.1975	0.2021	1.6956	1.8587	1.9153	5.04	6.82	-0.0897	24.35
7	-0.2254	0.3636	1.6648	1.7056	1.7451	5.05	7.32	-0.0939	24.10
8	-0.1901	0.5522	1.6207	1.8035	1.8422	5.07	7.88	-0.1163	24.00
9	-0.1941	0.6186	1.6161	1.8555	1.8880	5.07	8.17	-0.1045	23.75
10	-0.1890	0.7524	1.5825	1.7234	1.7679	5.06	8.72	-0.0685	24.25
11	-0.1639	0.8385	1.6120	2.2604	2.1013	5.08	9.11	-0.1077	24.35
12	-0.1530	1.0567	1.5855	1.6297	1.6664	5.08	9.57	-0.1006	24.15
13	-0.1589	1.1168	1.5523	1.8583	1.9001	5.07	10.09	-0.0974	24.10
14	-0.1688	1.3325	1.4889	1.6665	1.7212	5.08	11.06	-0.0012	24.35
15	-0.1630	1.3934	1.4673	1.7680	1.8490	5.07	11.39	-0.1087	24.05
16	-0.2015	1.4664	1.3890	1.6983	1.7576	5.07	12.03	-0.1050	24.35
17	-0.2158	1.5683	1.3500	1.4639	1.5258	5.04	12.37	-0.1122	24.30
18	-0.2294	1.6727	1.3159	1.6464	1.6867	5.05	12.92	-0.1205	24.20
19	-0.2325	1.7857	1.2569	1.4722	1.5157	5.06	13.39	-0.1154	24.25
20	-0.2276	1.8807	1.2278	1.7156	1.7949	5.05	13.89	-0.0363	24.25
21	-0.1847	1.9635	1.2417	1.6643	1.6983	5.04	14.41	-0.1156	24.35
22	-0.2086	2.0393	1.2178	1.6376	1.8774	5.04	14.78	-0.1253	24.45
23	-0.1625	2.2146	1.2105	1.5174	1.5782	5.03	15.22	-0.0370	24.40
24	-0.1551	2.2693	1.2058	1.7256	1.7707	5.03	15.69	-0.0424	23.95
25	-0.1690	2.3890	1.1469	1.7369	1.7932	5.02	16.31	-0.0983	24.35
26	-0.1648	2.4539	1.1215	1.9081	1.9536	5.04	17.10	-0.0994	24.05
27	-0.1563	2.5679	1.0805	1.8608	1.9109	5.03	17.57	-0.0890	24.10
28	-0.1467	2.6418	1.0583	1.6791	1.7100	5.03	18.32	-0.0982	23.75

TABLE 7

EXPERIMENTAL DATA FOR DILUTION RUN #6

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	-0.1561	5.6042		3.3246	3.2371				
INITIAL	-0.0813	1.1699	1.8107	0.1036	0.0782	4.9	5.12		
1	-0.0720	1.1541	1.8041	1.5487	1.5445	4.89	5.14	-0.1372	24.35
2	-0.0702	1.3087	1.7871	1.7289	1.7702	4.90	5.36	-0.1539	24.20
3	-0.0638	1.4719	1.7824	1.7642	1.7517	4.89	5.61	-0.1513	23.75
4	-0.0658	1.6534	1.7851	1.6711	1.7714	4.90	5.95	-0.1404	23.50
5	-0.0779	1.7671	1.7414	1.7456	1.7911	4.91	6.23	-0.1387	23.75
6	-0.0849	1.9117	1.7307	1.8440	1.8540	4.90	6.56	-0.1350	24.05
7	-0.0960	2.1630	1.6881	1.6991	1.8301	4.89	7.01	-0.1317	23.60
8	-0.0758	2.2093	1.6831	1.8201	1.8141	4.89	7.41	-0.1565	24.05
9	-0.0878	2.4859	1.6596	1.7428	1.7363	4.90	7.98	-0.1427	23.85
10	-0.0878	2.5781	1.6178	1.7399	1.7929	4.90	8.51	-0.1546	23.70
11	-0.0876	2.7144	1.5761	1.5866	1.6904	4.89	8.86	-0.1544	23.95
12	-0.0798	2.7946	1.5663	1.7526	1.7409	4.90	9.19	-0.1503	24.15
13	-0.0660	2.9051	1.5432	1.6441	1.7111	4.89	9.52	-0.1451	23.95
14	-0.0773	2.9192	1.5287	1.7517	1.8067	4.88	9.85	-0.1411	24.05
15	-0.0764	3.0672	1.4789	1.6449	1.6354	4.87	10.44	-0.1417	24.00
16	-0.0840	3.1590	1.4541	1.5864	1.5788	4.88	10.87	-0.1504	23.60
17	-0.0635	3.2219	1.4946	1.5586	1.5485	4.88	11.21	-0.1446	24.00
18	-0.0676	3.2961	1.4131	1.6883	1.7835	4.90	11.82	-0.1507	23.65
19	-0.0742	3.3500	1.3740	1.5939	1.5937	4.88	12.28	-0.1571	24.05
20	-0.0808	3.3749	1.3550	1.5542	1.7065	4.89	12.85	-0.1383	24.00
21	-0.0812	3.5157	1.3011	1.5117	1.6136	4.88	13.58	-0.1416	24.00
22	-0.0762	3.5740	1.2777	1.6399	1.7632	4.89	14.07	-0.1584	24.05
23	-0.1074	3.5761	1.2162	1.6731	1.6353	4.88	14.58	-0.1260	24.10
24	-0.1104	3.5966	1.1878	1.8697	1.7272	4.89	14.95	-0.1411	24.05
25	-0.1121	3.7061	1.1427	1.6395	1.4434	4.90	15.76	-0.1292	24.25
26	-0.1249	3.7857	1.1028	1.5585	1.6032	4.89	16.18	-0.1429	23.95
27	-0.1372	3.7883	1.0787	1.5991	1.6025	4.89	16.61	-0.1390	24.00
28	-0.1181	3.8149	1.0712	1.7100	1.6759	4.88	17.14	-0.1569	24.05
29	-0.1430	3.7924	1.0173	1.5544	1.5435	4.88	17.67	-0.1480	23.85
30	-0.1418	3.9245	0.9871	1.5578	1.6339	4.88	17.99	-0.1242	23.95
31	-0.1264	3.9228	0.9673	1.5500	1.5831	4.86	18.31	-0.1412	24.00
32	-0.1348	4.0052	0.9314	1.3804	1.3770	4.87	18.99	-0.1261	23.70
33	-0.0970	4.0378	0.9132	1.6417	1.6810	4.87	19.65	-0.1357	24.05
34	-0.0921	4.0395	0.8985	1.7184	1.7415	4.87	20.13	-0.1317	23.95

TABLE 7

EXPERIMENTAL DATA FOR DILUTION RUN #6 (CONTINUED)

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
35	-0.0840	4.0827	0.8763	1.5729	1.6089	4.86	20.61	-0.1397	24.25
36	-0.0737	4.1043	0.8389	1.6722	1.7685	4.86	21.24	-0.1374	24.05

TABLE 8

EXPERIMENTAL DATA FOR DILUTION RUN #7

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	-0.1543	7.4287		4.7222	4.7354				
INITIAL	0.0096	0.9025	1.9201	5.1825	5.1614	4.95	5.14		
1	-0.0161	0.9361	1.8822	1.3273	1.3465	4.93	5.43	-0.1131	24.00
2	-0.0341	1.0715	1.8209	1.8111	1.6711	4.94	5.65	-0.1094	24.05
3	-0.0518	1.2736	1.7769	1.1742	1.3041	4.93	6.11	-0.1281	23.75
4	-0.0573	1.4357	1.7467	1.5537	1.5510	4.95	6.38	-0.1188	23.90
5	-0.0792	1.5346	1.7272	1.4657	1.6412	4.91	6.69	-0.1323	24.15
6	-0.0889	1.6679	1.6817	1.4923	1.6579	4.91	7.06	-0.0993	24.05
7	-0.0972	1.7919	1.6646	1.3692	1.6532	4.91	7.36	-0.0884	23.95

TABLE 9

EXPERIMENTAL DATA FOR DILUTION RUN #8

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	-0.6498	10.3102		2.5715	2.5663				
INITIAL	-0.1526	2.1718	1.8742	-0.2147	-0.2390	4.93	5.12		
1	-0.1489	2.2089	1.7973	0.4483	0.3564	4.94	5.33	-0.1393	24.10
2	-0.2079	2.3449	1.7757	1.2332	1.2317	4.97	5.53	-0.1265	23.70
3	-0.1534	2.5279	1.7509	1.3383	1.3211	4.95	5.91	-0.0641	24.05
4	-0.1359	3.0511	1.7704	1.2997	1.2717	4.95	6.87	-0.1207	23.85
5	-0.1556	3.1803	1.6914	-0.5464	-0.2060	4.96	7.50	-0.1323	23.75
6	-0.1709	3.3120	1.6589	0.9898	0.9677	4.97	7.84	-0.1323	23.85
7	-0.1868	3.4426	1.6161	0.9522	0.9481	4.97	8.26	-0.1397	24.00
8	-0.1900	3.5469	1.5838	1.2591	1.2622	4.96	8.58	-0.1432	24.05
9	-0.1805	3.6675	1.5408	0.5154	0.8279	4.95	9.17	-0.1126	24.05
10	-0.1236	3.9466	1.5238	0.7732	1.0871	4.98	10.33	-0.0425	23.90
11	-0.1555	4.0496	1.5155	1.4131	1.3891	4.98	10.55	-0.1400	24.00
12	-0.2121	4.1310	1.4419	1.4254	1.4549	4.96	11.10	-0.1748	24.10
13	-0.2080	4.1503	1.4144	1.3617	1.5771	4.94	11.46	-0.1126	24.05
14	-0.1945	4.2800	1.3560	1.4049	1.5414	4.93	12.20	-0.1143	23.90
15	-0.1208	4.3896	1.3709	0.9494	1.3350	4.96	12.79	-0.1220	24.00
16	-0.1921	4.4542	1.3072	1.4318	1.6005	4.97	13.29	-0.1374	24.00
17	-0.2059	4.4706	1.2583	1.5708	1.6372	4.97	13.85	-0.1429	23.80
18	-0.1994	4.5251	1.2237	1.3912	1.4304	4.96	14.40	-0.1044	23.90
19	-0.1730	4.6121	1.1964	1.0790	1.4477	4.96	15.09	-0.1175	23.75
20	-0.1429	4.7297	1.1960	0.1961	0.8190	4.97	15.82	-0.1294	24.15
21	-0.1177	4.7782	1.2302	1.4067	1.4631	4.97	16.20	-0.1224	24.10
22	-0.1193	4.8274	1.1697	1.6320	1.6211	4.98	16.81	-0.1160	24.00
23	-0.1233	4.8851	1.1578	1.3352	1.4171	4.99	17.30	-0.1305	24.10
24	-0.1485	4.9028	1.1041	1.2785	1.3973	4.97	18.02	-0.1227	23.70
25	-0.1851	4.9400	1.0123	1.6069	1.5762	4.99	18.45	-0.1613	24.10
26	-0.2089	4.9017	0.9623	1.6050	1.6067	4.99	19.00	-0.1244	24.05
27	-0.2101	4.9567	0.9190	1.4987	1.5715	4.97	19.56	-0.1478	24.10
28	-0.1713	5.0106	0.8822	1.0103	1.3320	4.97	20.14	-0.0938	23.90
29	-0.1973	5.0306	0.8237	1.4984	1.5887	4.96	20.91	-0.1064	23.95
30	-0.1663	5.0730	0.8087	0.9900	1.4865	4.98	21.65	-0.1238	24.15

TABLE 10

EXPERIMENTAL DATA FOR DILUTION RUN #11

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	0.0429	7.5542		4.6967	4.814				
INITIAL	0.0004	2.4506	2.0513	0.9030	0.9118	4.92	5.46		
1	0.0048	2.5352	2.0450	1.5634	1.5577	5.07	5.82	-0.1282	24.00
2	0.0148	2.6499	2.0437	1.9345	1.9430	5.02	6.05	-0.1227	24.15
3	0.0212	2.8365	2.0138	1.6096	1.6195	5.03	6.57	-0.1516	24.05
4	0.0035	2.9657	1.9637	1.7789	1.8131	5.02	7.18	-0.1290	23.95
5	-0.0101	3.2320	1.8983	1.5907	1.6337	5.02	8.07	-0.1414	24.00
6	-0.0214	3.3291	1.8517	1.5696	1.6423	5.03	8.62	-0.1470	23.95
7	-0.0434	3.4388	1.8228	1.7322	1.8130	5.02	9.06	-0.1533	23.85
8	-0.0289	3.5569	1.7793	1.8949	1.9479	5.03	9.61	-0.0906	23.95
9	-0.0239	3.6980	1.7506	1.9572	1.9845	5.03	10.08	-0.1139	23.90
10	-0.0190	3.8365	1.7172	1.9599	1.9606	5.04	10.65	-0.1510	24.00
11	-0.0495	3.9312	1.6674	1.9273	1.9331	5.01	11.31	-0.0901	23.90
12	-0.0743	4.0312	1.6114	2.0617	2.0720	5.03	11.76	-0.1366	24.15
13	-0.0452	4.1562	1.5844	2.0140	1.9549	5.04	12.43	-0.1005	24.20
14	-0.0265	4.3012	1.5562	2.0610	2.0856	5.01	12.98	-0.1317	23.95
15	-0.0397	4.4449	1.5252	1.4421	1.6234	5.02	13.71	-0.0796	24.05
16	0.0031	4.5204	1.5130	2.0317	2.0824	5.02	14.07	-0.0795	23.90
17	-0.0014	4.6724	1.5119	2.0316	1.9660	5.01	14.62	-0.1486	23.65
18	-0.0203	4.7109	1.4677	2.1334	2.1756	5.01	15.05	-0.1235	24.00
19	-0.0048	4.7941	1.4345	2.1421	2.1020	5.02	15.61	-0.1162	24.00
20	-0.0009	4.9302	1.4146	2.0589	2.0350	5.01	16.14	-0.1259	24.00
21	0.0005	5.0739	1.3614	1.6724	1.7910	5.01	17.07	-0.1252	24.05
22	0.0213	5.1631	1.3507	2.1175	2.1510	5.01	17.53	-0.1235	23.90
23	0.0222	5.2425	1.3124	1.6586	1.8183	5.03	18.19	-0.1116	23.95
24	0.0196	5.3903	1.2607	1.2670	1.5629	5.03	19.23	-0.1284	24.05
25	0.0099	5.5196	1.1933	1.5356	1.7223	5.03	20.07	-0.1221	23.95
26	0.0246	5.6103	1.1614	1.9094	2.0113	5.02	20.76	-0.1209	23.95
27	0.0291	5.7073	1.1384	1.6888	1.7750	5.03	21.43	-0.1103	23.90

TABLE 11

EXPERIMENTAL DATA FOR DILUTION RUN #14

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	0.1383	4.7762		4.5506	4.6143				
INITIAL	1.212	3.0331	2.9005	5.0702	5.0538	7.25	7.46		
1	1.1828	3.2669	2.8552	1.6854	2.0098	7.24	8.00	-0.1659	23.90
2	1.1821	3.3933	2.8196	2.3756	2.4948	7.23	8.22	-0.1478	23.95
3	1.2058	3.6527	2.7970	2.3258	2.6391	7.24	8.72	-0.1476	23.95
4	1.2048	3.8556	2.7865	2.4097	2.7025	7.24	9.16	-0.1861	24.00
5.1	1.2053	3.9713	2.7603	2.3982	2.7183	7.24	9.52	-0.1628	23.95
5.2	1.4950	4.9784	3.0421	6.4103	6.4604	7.37	9.68		
6	1.5081	5.1232	3.0059	2.6753	2.9110	7.38	10.33	-0.1414	24.05
7	1.5187	5.2809	2.9891	2.5616	2.9549	7.39	10.69	-0.1476	24.10
8	1.5057	5.4537	2.9488	2.5994	2.9334	7.38	11.30	-0.1727	24.15
9	1.5051	5.5848	2.9157	2.6438	3.0197	7.39	11.89	-0.1727	24.00
10	1.4990	5.6705	2.8770	2.6003	2.9584	7.38	12.49	-0.1534	23.85
11	1.5005	5.8123	2.8165	2.4775	2.9991	7.39	13.26	-0.1491	24.20
12	1.4994	5.9376	2.7701	2.6837	3.0193	7.39	14.04	-0.1471	24.20
13	1.5001	6.0399	2.7014	2.7272	3.0537	7.40	14.73	-0.1252	24.05
14	1.4926	6.1177	2.6845	2.5630	2.9988	7.38	15.41	-0.1094	24.10
15	1.4849	6.2169	2.6384	2.6699	3.0370	7.38	16.09	-0.1505	24.10
16	1.4953	6.3252	2.5851	2.5487	2.9721	7.38	17.02	-0.1385	24.15
17	1.5043	6.4019	2.5291	2.6494	3.0885	7.38	18.12	-0.1395	24.15
18	1.4951	6.5074	2.4604	2.7569	3.0939	7.38	19.44	-0.1212	24.10
19	1.4811	6.5507	2.4001	2.6770	3.0816	7.39	20.26	-0.1371	23.95
20	1.4821	6.5929	2.2968	2.7160	3.0464	7.38	21.20	-0.1205	24.10
21	1.4733	6.6349	2.2392	2.7013	2.9505	7.39	22.02	-0.1257	23.95
22	1.4781	6.6773	2.1555	2.4756	2.7629	7.39	23.13	-0.1268	24.00
23	1.4512	6.7098	2.1294	2.4542	2.8202	7.38	24.28	-0.1302	23.90

TABLE 12

EXPERIMENTAL DATA FOR DILUTION RUN #15

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	1.4258	5.1184		4.3619	4.3765				
INITIAL	1.4053	3.6757	3.0925	2.0034	2.0236	7.37	7.56		
1	1.3977	3.8650	3.0458	1.4946	1.5224	7.39	8.13	-0.1556	24.00
2	1.3923	3.9367	3.0265	2.1541	2.1870	7.38	8.66	-0.1219	24.00
3	1.4001	4.1658	2.9705	2.2957	2.3369	7.38	9.32	-0.1492	23.85
4	1.4114	4.2907	2.9412	2.3032	2.3458	7.39	9.65	-0.1393	24.20
5	1.4163	4.4334	2.9075	2.5755	2.3787	7.38	10.36	-0.1139	23.95
6	1.4231	4.6186	2.8856	2.3473	2.4042	7.38	11.11	-0.1030	23.95
7	1.4147	4.8227	2.8391	2.2610	2.3188	7.37	12.12	-0.0950	24.00
8	1.4200	5.1144	2.7424	1.4669	1.5705	7.38	13.55	-0.1072	24.00
9	1.4251	5.2610	2.7108	2.5313	2.5797	7.38	14.05	-0.1412	24.15
10	1.4319	5.4019	2.6736	2.4993	2.5388	7.39	14.87	-0.1134	24.05
11	1.4403	5.5543	2.5941	2.5587	2.6074	7.39	15.70	-0.1101	23.95
12	1.4500	5.7077	2.5742	2.5376	2.5783	7.39	16.54	-0.1423	23.90

TABLE 13

EXPERIMENTAL DATA FOR DILUTION RUN #16

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	1.4502	4.2467		4.3080	4.3587				
INITIAL	1.4563	3.9456	3.1057	1.4867	1.5001	7.38	7.7		
1	1.4643	5.5315	2.7282	1.0153	1.0708	7.38	14.30	-0.1309	23.95
2	1.4662	5.6650	2.6700	2.7150	2.7469	7.39	15.01	-0.1124	23.90
3	1.4533	5.8372	2.6146	2.7419	2.7732	7.38	15.93	-0.1246	23.90
4	1.4546	5.9970	2.5591	2.7732	2.8232	7.39	16.89	-0.1169	24.05
5	1.4473	6.1656	2.4913	2.8688	2.5796	7.38	17.98	-0.1253	24.00
6	1.4554	6.2837	2.4503	2.7778	2.8305	7.38	18.91	-0.0905	23.90
7	1.4505	6.4654	2.3553	2.7821	2.8296	7.40	20.16	-0.0961	24.05
8	1.4572	6.6271	2.3051	2.9022	2.9534	7.39	21.18	-0.1170	23.95
9	1.4519	6.7853	2.2343	2.7568	2.9824	7.38	22.37	-0.1187	24.05

TABLE 14

EXPERIMENTAL DATA FOR DILUTION RUN #17

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	1.6693	4.8263		4.7747	4.8066				
INITIAL	1.4803	3.6977	3.1551	0.5530	0.6344	7.41	7.53		
1	1.4998	3.9899	3.1422	3.6494	3.6711	7.42	7.81	-0.0970	23.95
2	1.4938	4.2256	3.1104	3.6239	3.6384	7.42	8.16	-0.0999	23.90
3	1.4958	4.5621	3.0732	3.4939	3.5097	7.41	8.87	-0.0919	24.00
4	1.4973	4.9340	3.0210	3.6207	3.6539	7.41	9.79	-0.0893	24.00
5	1.5001	5.2574	2.9668	3.6376	3.6570	7.42	10.90	-0.1067	23.90
6	1.6885	5.7181	3.0525	3.6955	3.7186	7.43	11.65	-0.1004	23.85
7	1.4972	5.8613	2.8503	3.4873	3.5042	7.41	12.73	-0.0955	24.00
8	1.5002	6.0487	2.7830	3.5488	3.5758	7.40	13.71	-0.0915	23.95
9	1.5309	6.2841	2.7352	3.5981	3.6202	7.43	14.60	-0.1062	23.80
10	1.4966	6.6116	2.6504	3.5594	3.5835	7.41	15.65	-0.1057	23.85
11	1.4912	6.6322	2.5494	3.7559	3.7918	7.42	16.48	-0.1067	24.05
12	1.4924	6.7105	2.5061	3.6312	3.6522	7.40	17.47	-0.0916	24.00
13	1.4995	6.7949	2.4534	3.5287	3.5502	7.42	18.57	-0.1028	24.00
14	1.4991	6.8284	2.3932	3.6175	3.6390	7.41	19.40	-0.1109	23.90
15	1.4864	6.8888	2.3011	3.5683	3.5959	7.40	20.81	-0.0942	23.75
16	1.4971	6.9591	2.2562	3.6075	3.6398	7.40	21.98	-0.0939	24.00
17	1.4780	7.0082	2.1492	3.6066	3.6387	7.40	23.28	-0.1004	23.95
18	1.4728	7.0710	2.0440	3.5775	3.6031	7.40	24.59	-0.1064	24.00

TABLE 15

EXPERIMENTAL DATA FOR DILUTION RUN #18

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	1.4733	4.4019		4.4671	4.5049				
INITIAL	1.4761	3.165	3.1183	1.9499	1.9903	7.41	7.53		
1	1.4586	3.2160	3.1107	3.4934	3.5430	7.40	7.70	-0.1475	24.05
2	1.4653	3.3559	3.0587	3.6070	3.6483	7.39	8.23	-0.1453	23.80
3	1.4487	3.5698	3.0041	3.5052	3.5616	7.40	8.71	-0.1470	24.00
4	1.4704	3.7520	2.9751	3.4841	3.7107	7.39	9.19	-0.1370	24.00
5	1.4464	3.9385	2.9523	3.4342	3.5579	7.39	9.85	-0.1698	24.00
6	1.4577	4.1639	2.9334	3.4355	3.5582	7.40	10.61	-0.1409	23.90
7	1.4753	4.3852	2.8953	3.5083	3.5157	7.39	11.33	-0.1292	24.00
8	1.4634	4.5803	2.8629	3.5451	3.5131	7.39	12.00	-0.1465	24.05
9	1.4760	4.7725	2.8170	3.5446	3.6673	7.39	12.86	-0.1482	24.05
10	1.4691	5.0036	2.7539	3.3911	3.4403	7.39	13.80	-0.1295	24.00
11	1.4767	5.2522	2.6840	3.4965	3.5224	7.37	14.92	-0.1353	23.95

TABLE 16

EXPERIMENTAL DATA FOR DILUTION RUN #19

TILT #	CR	C	A	C2	C1	BR	B	del C pi	del U
LOAD	1.4677	4.4802		4.5317	4.5457				
INITIAL	1.4656	2.7230	3.1433	2.4702	2.4996	7.39	7.53		
1	1.4867	4.7768	2.8637	5.5585	5.6044	7.37	12.01	-0.1244	23.95
2	1.4750	5.0968	2.7595	3.9863	4.0257	7.38	13.80	-0.1373	23.95
3	1.4825	5.0501	2.7177	3.8437	3.8914	7.39	14.55	-0.1423	24.00
4	1.4857	5.0127	2.6963	4.0530	4.1912	7.38	15.06	-0.2313	24.05
5	1.4673	5.0745	2.6071	5.3330	5.3741	7.38	16.19	-0.1438	24.00
6	1.4781	5.3506	2.5121	3.6876	3.7224	7.39	17.90	-0.0954	23.95
7	1.4813	5.4986	2.4756	3.5270	3.5583	7.38	18.69	-0.1088	24.10
8	1.4793	5.7094	2.3951	3.5507	3.5914	7.39	19.99	-0.0886	24.00
9	1.5002	5.9557	2.3265	3.5816	3.6145	7.38	21.40	-0.0854	23.90

APPENDIX C

CALCULATED DATA

NOMENCLATURE FOR APPENDIX C

CTOT	Cumulative change in height of mercury in C
del A	Change in height of mercury in mixing bowl
del B	Change in height of mercury in buret
del C, C1, C2	Change in height of mercury in a capillary
del n_c	Number of moles of solute added to solvent
del V_c	Volume of solute added to the solvent
del V_{em}	Excess molar volume of mixing
n_cTOT	Total number of moles of solute in mixing bowl
x (Benz)	Mole fraction of benzene in mixing bowl

APPENDIX C-1

SPREADSHEET GENERATED DATA

TABLE 17

CALCULATED DATA FOR DILUTION RUN #2

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.17	2.5873	2.1567	0.2726	-0.0446	0.21754	0.00200	0.00200	0.98259	0.2726	0.00569	0.048985
2	0.13	0.2488	0.4232	0.1467	-0.0268	0.11391	0.00104	0.00304	0.97372	0.4193	0.00792	0.068332
3	0.09	0.1752	0.4516	0.1075	0.0657	0.08173	0.00075	0.00379	0.96745	0.5268	0.00819	0.070150
4	0.12	0.8436	0.7666	0.1295	-0.0659	0.12271	0.00112	0.00492	0.95819	0.6563	0.01283	0.108880
5	0.06	0.7664	0.9173	0.1385	0.0148	0.07695	0.00070	0.00563	0.95247	0.7948	0.01385	0.116851
6	0.12	0.6753	0.5941	0.0997	-0.0456	0.11666	0.00107	0.00670	0.94394	0.8945	0.01668	0.139468
7	0.48	-1.5104	-2.0987	0.3619	-0.0120	0.31251	0.00287	0.00958	0.92180	1.2564	0.02249	0.183574
8	0.66	-1.2933	-0.7191	0.5403	-0.0140	0.48208	0.00443	0.01401	0.88961	1.7967	0.03214	0.253147
9	0.53	-0.1866	-0.3739	0.4206	-0.0193	0.40584	0.00373	0.01774	0.86421	2.2173	0.03971	0.303852
10	0.16	0.0364	-0.0824	0.1122	-0.0426	0.12470	0.00114	0.01889	0.85670	2.3295	0.04210	0.319363
11	0.23	0.5613	0.8409	0.2211	-0.0146	0.20532	0.00188	0.02078	0.84460	2.5506	0.04554	0.340557
12	0.56	-0.4124	-0.7191	0.3892	-0.0477	0.41935	0.00385	0.02463	0.82093	2.9398	0.05301	0.385329
13	0.13	-0.1426	0.1329	0.0613	-0.0047	0.10181	0.00093	0.02557	0.81538	3.0011	0.05337	0.385392
14	0.24	0.9399	1.0112	0.2211	-0.0183	0.22290	0.00204	0.02762	0.80349	3.2222	0.05758	0.409599
15	0.64	-1.0333	-1.1173	0.3064	-0.0172	0.46392	0.00426	0.03188	0.77983	3.5286	0.06286	0.433999
16	0.17	0.0319	0.0577	0.1387	-0.0014	0.13495	0.00124	0.03313	0.77320	3.6673	0.06515	0.446027
17	0.69	-0.0184	-0.0265	0.4841	-0.0295	0.54052	0.00497	0.03810	0.74776	4.1514	0.07426	0.491665
18	0.32	-0.0418	-0.0154	0.1622	-0.0351	0.25009	0.00229	0.04040	0.73655	4.3136	0.07721	0.503508
19	0.37	0.1062	0.1107	0.2209	-0.0140	0.29412	0.00270	0.04310	0.72379	4.5345	0.08072	0.517239
20	0.29	0.0620	0.0506	0.1737	-0.0291	0.22950	0.00211	0.04521	0.71413	4.7082	0.08409	0.531683
21	0.19	-0.1171	-0.0843	0.0986	0.0259	0.14548	0.00133	0.04655	0.70814	4.8068	0.08487	0.532071
22	0.49	-0.2070	-0.1851	0.2429	-0.0505	0.37745	0.00347	0.05002	0.69306	5.0497	0.09051	0.555400
23	0.39	0.0956	0.0752	0.1851	-0.0274	0.30899	0.00284	0.05286	0.68118	5.2348	0.09356	0.564226
24	0.24	0.0551	0.0711	0.0732	-0.0327	0.19052	0.00175	0.05461	0.67406	5.3080	0.09477	0.565601
25	0.70	-0.0102	0.0484	0.3262	-0.0477	0.54984	0.00505	0.05967	0.65432	5.6342	0.10077	0.583754
26	0.23	0.0513	-0.0448	0.1215	0.0079	0.18055	0.00166	0.06133	0.64809	5.7557	0.10201	0.585293
27	0.12	0.1375	0.1583	0.0512	0.0011	0.09939	0.00091	0.06224	0.64471	5.8069	0.10314	0.588741
28	0.19	-0.0850	-0.1026	0.0924	-0.0207	0.14572	0.00134	0.06358	0.63981	5.8993	0.10515	0.595641
29	0.12	0.0436	0.0468	0.0534	-0.0304	0.09574	0.00088	0.06446	0.63664	5.9527	0.10618	0.598474
30	0.48	-0.1608	-0.1109	0.1935	-0.0298	0.37174	0.00341	0.06788	0.62460	6.1462	0.10970	0.606660
31	0.23	0.0610	0.0831	0.1126	0.0116	0.18299	0.00168	0.06956	0.61884	6.2588	0.11091	0.607657
32	0.31	0.0850	0.0724	0.0962	-0.0373	0.24599	0.00226	0.07183	0.61127	6.3550	0.11342	0.613835
33	0.27	-0.2315	-0.2178	0.1037	0.0005	0.20384	0.00187	0.07370	0.60513	6.4587	0.11459	0.613927
34	0.29	0.2093	0.1986	0.1400	-0.0211	0.23474	0.00215	0.07586	0.59821	6.5987	0.11752	0.622424

TABLE 17

CALCULATED DATA FOR DILUTION RUN #2 (CONTINUED)

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
35	0.33	-0.0421	-0.0912	0.1150	-0.0223	0.25652	0.00235	0.07822	0.59083	6.7137	0.11964	0.625833
36	0.26	-0.0679	-0.0409	0.0951	-0.0070	0.20204	0.00185	0.08008	0.58514	6.8088	0.12104	0.627072
37	0.25	0.1711	0.1878	0.1032	-0.0099	0.20249	0.00186	0.08194	0.57955	6.9120	0.12282	0.630177
38	0.44	-0.1362	-0.2524	0.1390	-0.0642	0.33829	0.00311	0.08505	0.57045	7.0510	0.12633	0.638050
39	0.28	0.0872	0.2020	0.1130	0.0321	0.22479	0.00206	0.08712	0.56456	7.1640	0.12663	0.632918
40	0.41	-0.3160	-0.0278	0.1377	-0.0373	0.31555	0.00290	0.09002	0.55648	7.3017	0.13035	0.642213
41	0.27	0.3213	0.0426	0.0946	-0.0158	0.21827	0.00200	0.09203	0.55104	7.3963	0.13156	0.641809
42	0.38	-0.0001	-0.0177	0.1239	-0.0514	0.29780	0.00273	0.09476	0.54377	7.5202	0.13425	0.646297
43	0.32	-0.0757	-0.0611	0.1215	-0.0305	0.24861	0.00228	0.09705	0.53785	7.6417	0.13627	0.648083
44	0.90	-0.1663	-0.1746	0.2589	-0.0213	0.70001	0.00643	0.10349	0.52186	7.9006	0.14063	0.649757
45	0.38	0.1450	0.1692	0.1062	-0.0579	0.30369	0.00279	0.10628	0.51521	8.0068	0.14309	0.652676
46	0.60	-0.1200	-0.1380	0.1665	0.0088	0.46613	0.00428	0.11057	0.50533	8.1733	0.14492	0.648356
47	0.56	0.1481	0.1710	0.1458	-0.0376	0.44499	0.00409	0.11466	0.49624	8.3191	0.14818	0.651022
48	0.42	-0.1504	-0.1547	0.1062	-0.0063	0.32408	0.00298	0.11764	0.48983	8.4253	0.14964	0.648933
49	0.46	0.2376	0.2248	0.1595	-0.0385	0.36908	0.00339	0.12103	0.48273	8.5848	0.15286	0.653309
50	0.46	-0.0328	-0.0145	0.1399	0.0228	0.36004	0.00331	0.12434	0.47599	8.7247	0.15434	0.650431

VOLUME OF BENZENE CHARGED RUN #2= 10.0983
MOLES OF BENZENE CHARGED RUN #2= 0.11295

TABLE 18

CALCULATED DATA FOR DILUTION RUN #3

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vam (P CORR)
1	0.10	1.8114	1.8127	0.2553	0.0087	0.14276	0.00159	0.00159	0.01419	0.2553	0.00437	0.038921
2	0.20	0.1724	0.1661	0.2161	-0.0407	0.16291	0.00182	0.00341	0.02991	0.2161	0.00454	0.039805
3	0.15	0.0195	0.0185	0.2088	0.0002	0.11835	0.00132	0.00474	0.04102	0.2088	0.00370	0.032020
4	0.30	-0.0189	-0.0271	0.3229	-0.0172	0.23459	0.00262	0.00736	0.06230	0.3229	0.00602	0.051000
5	0.16	-0.0184	-0.0078	0.2231	-0.0144	0.12505	0.00139	0.00876	0.07327	0.2231	0.00421	0.035235
6	0.22	-0.0673	-0.0634	0.2569	-0.0198	0.17027	0.00190	0.01066	0.08779	0.2569	0.00491	0.040415
7	0.20	0.1145	0.1136	0.1935	-0.0021	0.16095	0.00180	0.01247	0.10111	0.1935	0.00346	0.028128
8	0.14	-0.0829	-0.0895	0.1487	-0.0245	0.10677	0.00119	0.01366	0.10973	0.1487	0.00307	0.024666
9	0.15	0.0869	0.0919	0.1295	0.0514	0.12085	0.00135	0.01501	0.11929	0.1295	0.00138	0.011004
10	0.26	0.0100	0.0152	0.2769	-0.0621	0.20442	0.00228	0.01730	0.13500	0.2769	0.00601	0.046912
11	0.17	0.0553	0.0483	0.1795	-0.0251	0.13520	0.00151	0.01881	0.14509	0.1795	0.00363	0.028008
12	0.13	0.0250	0.0349	0.0979	0.0032	0.10305	0.00115	0.01996	0.15262	0.0979	0.00167	0.012839
13	0.18	-0.1046	-0.1018	0.1575	0.0053	0.13755	0.00153	0.02150	0.16247	0.1575	0.00269	0.020387
14	0.35	-0.2416	-0.2594	0.2659	-0.0189	0.26579	0.00297	0.02447	0.18087	0.2659	0.00505	0.037324
15	0.21	0.2382	0.2365	0.1832	-0.0302	0.17317	0.00193	0.02641	0.19243	0.1832	0.00378	0.027575
16	0.11	-0.0923	-0.1084	0.1010	-0.0057	0.08273	0.00092	0.02734	0.19783	0.1010	0.00189	0.013707
17	0.20	0.0953	0.1033	0.1330	0.0038	0.16042	0.00179	0.02913	0.20811	0.1330	0.00229	0.016369
18	0.16	-0.0171	-0.0052	0.1229	-0.0125	0.12512	0.00139	0.03053	0.21595	0.1229	0.00240	0.016993
19	0.18	-0.0610	-0.0771	0.1294	-0.0119	0.13876	0.00155	0.03208	0.22447	0.1294	0.00250	0.017596
20	0.22	0.1360	0.1531	0.1668	-0.0267	0.17772	0.00198	0.03407	0.23510	0.1668	0.00343	0.023685
21	0.16	0.0352	0.0394	0.0661	-0.0098	0.12684	0.00141	0.03549	0.24252	0.0661	0.00134	0.009201
22	0.19	-0.1003	-0.1274	0.1438	0.0048	0.14501	0.00162	0.03711	0.25082	0.1438	0.00246	0.016671
23	0.20	0.0102	0.0390	0.1094	-0.0183	0.15777	0.00176	0.03888	0.25965	0.1094	0.00226	0.015132
24	0.20	-0.0654	-0.0930	0.1058	-0.0293	0.15409	0.00172	0.04060	0.26808	0.1058	0.00239	0.015816
25	0.18	0.0622	0.0854	0.1224	0.0043	0.14383	0.00160	0.04221	0.27577	0.1224	0.00209	0.013685
26	0.19	-0.0568	-0.0571	0.1133	-0.0201	0.14703	0.00164	0.04385	0.28347	0.1133	0.00236	0.015292
27	0.14	-0.0318	-0.0171	0.0857	0.0008	0.10896	0.00121	0.04507	0.28907	0.0857	0.00150	0.009658
28	0.20	0.0313	0.0229	0.0922	-0.0209	0.15786	0.00176	0.04684	0.29703	0.0922	0.00200	0.012715
29	0.12	-0.0647	-0.0647	0.0954	-0.0012	0.09184	0.00102	0.04787	0.30158	0.0954	0.00171	0.010802
30	0.21	-0.0437	-0.0496	0.0824	-0.0129	0.16309	0.00182	0.04969	0.30951	0.0824	0.00169	0.010527
31	0.20	0.1287	0.1276	0.0566	-0.0142	0.16145	0.00180	0.05150	0.31719	0.0566	0.00125	0.007739
32	0.41	-0.0933	-0.1305	0.2098	-0.0077	0.31768	0.00355	0.05505	0.33182	0.2098	0.00385	0.023258
33	0.18	0.0241	0.0456	0.1127	-0.0179	0.14245	0.00159	0.05664	0.33817	0.1127	0.00231	0.013839
34	0.15	0.0637	0.0655	0.0769	-0.0092	0.11997	0.00134	0.05798	0.34343	0.0769	0.00152	0.009051

TABLE 18

CALCULATED DATA FOR DILUTION RUN #3 (CONTINUED)

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
35	0.22	0.0879	0.1024	0.1641	-0.0122	0.17597	0.00196	0.05995	0.35100	0.1641	0.00313	0.018332
36	0.23	-0.1033	-0.1261	0.0910	-0.0058	0.17636	0.00197	0.06193	0.35841	0.0910	0.00171	0.009939
37	0.23	0.0676	0.0554	0.0833	-0.0322	0.18262	0.00204	0.06397	0.36590	0.0833	0.00204	0.011721
38	0.19	0.0232	0.0402	0.0690	-0.0043	0.15018	0.00167	0.06565	0.37194	0.0690	0.00130	0.007368
39	0.24	-0.1472	-0.1432	0.1081	-0.0190	0.18313	0.00204	0.06770	0.37914	0.1081	0.00225	0.012629
40	0.22	0.0116	0.0293	0.0912	-0.0215	0.17332	0.00193	0.06964	0.38581	0.0912	0.00199	0.011078
41	0.21	0.0986	0.0994	0.0909	0.0013	0.16826	0.00188	0.07152	0.39215	0.0909	0.00159	0.008721
42	0.32	0.0448	0.0455	0.0990	-0.0349	0.25264	0.00282	0.07434	0.40142	0.0990	0.00237	0.012824
43	0.16	-0.0122	-0.0039	0.0716	0.0096	0.12523	0.00140	0.07574	0.40592	0.0716	0.00110	0.005896
44	0.25	0.0217	0.0132	0.0832	-0.0211	0.19674	0.00220	0.07795	0.41284	0.0832	0.00185	0.009805
45	0.20	0.0404	-0.0085	0.0900	-0.0101	0.15746	0.00176	0.07971	0.41827	0.0900	0.00177	0.009319
46	0.25	-0.0680	-0.0250	0.0711	-0.0132	0.19448	0.00217	0.08188	0.42483	0.0711	0.00149	0.007762
47	0.17	-0.1079	-0.1079	0.0483	-0.0079	0.12953	0.00144	0.08333	0.42912	0.0483	0.00099	0.005193
48	0.21	0.0553	0.0610	0.0998	-0.0238	0.16681	0.00186	0.08520	0.43456	0.0998	0.00219	0.011190
49	0.29	-0.0450	-0.0521	0.0808	-0.0036	0.22578	0.00252	0.08772	0.44175	0.0808	0.00149	0.007546
50	0.21	0.0573	0.0555	0.0785	-0.0173	0.16675	0.00186	0.08959	0.44694	0.0785	0.00170	0.008487
51	0.38	-0.0267	-0.0231	0.0805	-0.0226	0.29723	0.00332	0.09291	0.45597	0.0805	0.00182	0.008970
52	0.23	0.0665	0.0586	0.0915	-0.0216	0.18265	0.00204	0.09496	0.46137	0.0915	0.00200	0.009758
53	0.27	-0.0272	-0.0202	0.0811	0.0087	0.21097	0.00235	0.09732	0.46747	0.0811	0.00128	0.006173
54	0.26	-0.0355	-0.0249	0.0662	-0.0444	0.20290	0.00226	0.09959	0.47321	0.0662	0.00196	0.009330
55	0.32	0.0303	0.0261	0.0821	-0.0106	0.25204	0.00281	0.10240	0.48018	0.0821	0.00164	0.007712
56	0.26	-0.0221	-0.0279	0.0773	0.0023	0.20309	0.00227	0.10468	0.48566	0.0773	0.00133	0.006174

VOLUME OF T-C-E CHARGED RUN #3= 9.91122
MOLES OF T-C-E CHARGED RUN #3= 0.11086

TABLE 19

CALCULATED DATA FOR DILUTION RUN #4

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BEN2)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.02	3.0082	3.0812	0.2007	-0.0088	0.12374	0.00137	0.00137	0.98775	0.2007	0.00970	0.032925
2	0.09	0.3788	0.3398	0.1683	-0.0028	0.08335	0.00092	0.00230	0.97967	0.3690	0.00659	0.058193
3	0.14	-0.0313	-0.0203	0.0563	-0.0157	0.10891	0.00121	0.00351	0.96930	0.4253	0.00782	0.068311
4	0.24	-0.6900	-0.6970	0.1050	-0.0607	0.16367	0.00182	0.00533	0.95414	0.5303	0.01047	0.090015
5	0.51	-0.2588	-0.6232	0.2762	-0.0178	0.38444	0.00427	0.00961	0.92031	0.8065	0.01463	0.121237
6	0.28	0.7050	0.7834	0.0969	-0.0163	0.24607	0.00273	0.01235	0.89989	0.9034	0.01631	0.132179
7	0.19	-0.3212	-0.2298	0.0988	0.0247	0.13928	0.00154	0.01390	0.88873	1.0022	0.01736	0.138927
8	0.10	0.6767	0.8594	0.0730	0.0026	0.10560	0.00117	0.01507	0.88045	1.0752	0.01903	0.150946
9	0.20	-0.4883	-0.4724	0.0707	-0.0221	0.13985	0.00155	0.01663	0.86972	1.1459	0.02072	0.162927
10	0.23	0.2244	-0.2482	0.0836	-0.0600	0.18001	0.00200	0.01863	0.85629	1.2295	0.02286	0.176276
11	0.13	0.2064	0.6951	0.0505	0.0103	0.11799	0.00131	0.01995	0.84771	1.2800	0.02255	0.172161
12	0.53	-0.6174	-1.0909	0.1861	-0.0566	0.38547	0.00428	0.02423	0.82084	1.4661	0.02701	0.199639
13	0.14	0.3646	0.5679	0.0959	0.0459	0.12638	0.00140	0.02564	0.81239	1.5620	0.02692	0.196983
14	0.23	-0.1084	-0.0206	0.0445	-0.0350	0.17815	0.00198	0.02762	0.80078	1.6065	0.02911	0.209921
15	0.28	-0.0453	-0.1392	0.0938	-0.0262	0.21649	0.00240	0.03003	0.78711	1.7003	0.03065	0.217255
16	0.43	-0.1493	-0.2626	0.1007	-0.0196	0.33003	0.00367	0.03370	0.76714	1.8010	0.03247	0.224358
17	0.08	0.1399	0.2595	0.0727	0.0018	0.06974	0.00077	0.03448	0.76305	1.8737	0.03326	0.228543
18	0.15	0.1354	0.1577	-0.0285	-0.0064	0.12287	0.00136	0.03585	0.75595	1.8452	0.03283	0.223511
19	0.30	-0.0585	-0.2733	0.0350	-0.0242	0.22946	0.00255	0.03840	0.74303	1.8802	0.03377	0.225977
20	0.35	-0.1704	0.2948	0.0714	-0.0127	0.27679	0.00307	0.04148	0.72803	1.9516	0.03493	0.229027
21	0.35	-0.0427	-0.1377	0.0117	-0.0130	0.27137	0.00301	0.04450	0.71390	1.9633	0.03505	0.225309
22	0.66	-0.1817	-0.4429	0.1629	-0.0438	0.50669	0.00563	0.05014	0.68893	2.1262	0.03850	0.238882
23	0.41	0.1792	0.3489	0.0724	-0.0396	0.33102	0.00368	0.05382	0.67354	2.1986	0.03971	0.240861
24	0.31	0.2725	0.1226	0.0924	-0.0130	0.25021	0.00278	0.05661	0.66236	2.2910	0.04089	0.243926
25	0.39	-0.0627	0.0857	0.0491	-0.0058	0.30637	0.00340	0.06002	0.64916	2.3401	0.04163	0.243340
26	0.37	-0.0809	-0.0359	0.0675	-0.0243	0.28820	0.00320	0.06322	0.63721	2.4076	0.04312	0.247412
27	0.50	0.1535	0.1503	0.0446	-0.0278	0.39765	0.00442	0.06765	0.62144	2.4522	0.04395	0.245977
28	0.29	-0.0361	-0.0089	0.0845	-0.0127	0.22671	0.00252	0.07017	0.61279	2.5367	0.04522	0.249529
29	0.30	-0.1317	-0.0785	-0.0142	-0.0231	0.23162	0.00257	0.07275	0.60419	2.5225	0.04521	0.245985
30	0.34	0.1644	-0.0010	0.0163	-0.0420	0.26963	0.00300	0.07575	0.59449	2.5388	0.04582	0.245325
31	0.47	0.0395	0.2277	0.0184	-0.0284	0.37346	0.00415	0.07990	0.58155	2.5572	0.04592	0.240479
32	0.35	-0.2528	-0.2202	0.0498	-0.0362	0.26618	0.00296	0.08287	0.57267	2.6070	0.04687	0.241702
33	0.55	0.3518	0.3683	0.0544	0.0986	0.44426	0.00494	0.08781	0.55844	2.6614	0.04544	0.228508
34	0.48	-0.0008	-0.2018	0.0513	-0.0709	0.37297	0.00415	0.09196	0.54702	2.7127	0.04933	0.243000

TABLE 19

CALCULATED DATA FOR DILUTION RUN #4 (CONTINUED)

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
35	0.43	0.0803	0.0766	0.0923	0.0093	0.34012	0.00378	0.09574	0.53701	2.8050	0.04967	0.240220
36	0.56	-0.0754	0.0197	0.0233	-0.0093	0.43834	0.00487	0.10062	0.52464	2.8283	0.05037	0.237981
37	0.92	-0.0779	-0.2174	0.0601	-0.0697	0.71651	0.00797	0.10859	0.50559	2.8884	0.05249	0.239001
38	0.53	0.2481	0.2286	0.0554	-0.0144	0.42425	0.00472	0.11331	0.49496	2.9438	0.05251	0.234067
39	0.66	0.0769	0.1855	0.0155	-0.0398	0.52244	0.00581	0.11913	0.48246	2.9593	0.05320	0.231137
40	0.54	-0.1146	0.0375	0.0401	-0.0446	0.42227	0.00469	0.12383	0.47281	2.9994	0.05401	0.229943
41	0.71	0.0716	-0.0144	0.0101	-0.0309	0.55802	0.00620	0.13004	0.46063	3.0095	0.05388	0.223501
42	0.79	-0.0389	-0.1571	0.0264	-0.0099	0.61629	0.00685	0.13689	0.44789	3.0359	0.05390	0.217407
43	0.90	0.1829	0.2408	0.1138	-0.0291	0.71958	0.00794	0.14483	0.43399	3.1497	0.05646	0.220670

VOLUME OF BENZENE CHARGED RUN #4= 9.92877

MOLES OF BENZENE CHARGED RUN #4= 0.11105

TABLE 20

CALCULATED DATA FOR DILUTION RUN #5

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.07	2.1064	2.1096	0.0145	0.0419	0.12972	0.00145	0.00145	0.01301	0.0145	-0.0004	-0.00435
2	0.33	-0.1463	-0.1188	0.0699	-0.0515	0.25418	0.00284	0.00429	0.03754	0.0844	0.00241	0.021074
3	0.24	0.0774	0.0871	0.1651	-0.0004	0.19120	0.00213	0.00643	0.05521	0.2495	0.00443	0.038050
4	0.33	-0.0091	0.0037	0.0634	-0.0048	0.25879	0.00289	0.00932	0.07811	0.3129	0.00563	0.047180
5	0.32	-0.0797	-0.0911	0.0641	-0.0429	0.24801	0.00277	0.01210	0.09904	0.3770	0.00745	0.061023
6	0.30	0.0959	0.0814	0.0918	-0.0103	0.23850	0.00266	0.01476	0.11829	0.4688	0.00849	0.068054
7	0.49	-0.1423	-0.1252	0.1894	-0.0029	0.37966	0.00424	0.01901	0.14729	0.6582	0.01172	0.090837
8	0.54	0.0618	0.0626	0.1539	-0.0794	0.42584	0.00476	0.02377	0.17764	0.8115	0.01581	0.118168
9	0.29	0.0498	0.0560	0.0704	-0.0006	0.22938	0.00256	0.02634	0.19310	0.8819	0.01566	0.114801
10	0.56	-0.1252	-0.1972	0.1287	-0.0387	0.43467	0.00486	0.03120	0.22087	1.0106	0.01859	0.131596
11	0.37	0.3083	0.5119	0.0610	0.0044	0.30482	0.00340	0.03461	0.23923	1.0716	0.01894	0.130895
12	0.46	-0.4458	-0.6416	0.2073	-0.0374	0.34158	0.00382	0.03843	0.25880	1.2789	0.02335	0.157255
13	0.53	0.2396	0.2345	0.0660	-0.0273	0.42420	0.00474	0.04318	0.28175	1.3449	0.02434	0.158838
14	0.96	-0.1690	-0.1819	0.2256	-0.0535	0.74691	0.00835	0.05153	0.31887	1.5705	0.02869	0.177559
15	0.34	0.1220	0.0957	0.0551	-0.0274	0.27059	0.00302	0.05456	0.33139	1.6256	0.02934	0.178200
16	0.64	-0.0529	-0.0312	0.1115	-0.0398	0.50060	0.00559	0.06016	0.35339	1.7371	0.03153	0.185219
17	0.37	-0.2175	-0.2201	0.1162	-0.0247	0.28250	0.00315	0.06332	0.36517	1.8533	0.03333	0.192248
18	0.54	0.1745	0.1961	0.1180	-0.0205	0.43021	0.00481	0.06813	0.38231	1.9713	0.03537	0.198464
19	0.46	-0.1679	-0.1711	0.1161	-0.0559	0.35486	0.00396	0.07210	0.39577	2.0874	0.03805	0.208861
20	0.51	0.2743	0.2385	0.0901	-0.0340	0.40920	0.00457	0.07668	0.41057	2.1775	0.03913	0.209543
21	0.53	-0.1395	-0.0942	0.0399	-0.0290	0.41164	0.00460	0.08128	0.42476	2.2174	0.03988	0.208402
22	0.37	0.2030	-0.0028	0.0997	.0000	0.29382	0.00328	0.08457	0.43447	2.3171	0.04115	0.211411
23	0.45	-0.3453	-0.1663	0.1292	-0.0534	0.34395	0.00384	0.08842	0.44549	2.4463	0.04423	0.222848
24	0.47	0.1851	0.2008	0.0473	-0.0121	0.37557	0.00420	0.09262	0.45692	2.4936	0.04435	0.218809
25	0.63	0.0364	0.0252	0.1336	-0.0450	0.49534	0.00554	0.09816	0.47137	2.6272	0.04740	0.227654
26	0.77	0.1562	0.1670	0.0607	-0.0296	0.60981	0.00682	0.10498	0.48814	2.6879	0.04821	0.224192
27	0.48	-0.0512	-0.0558	0.1055	-0.0495	0.37467	0.00419	0.10917	0.49792	2.7934	0.05041	0.229954
28	0.75	-0.2105	-0.1973	0.0643	-0.0918	0.58115	0.00650	0.11567	0.51238	2.8577	0.05126	0.227093

VOLUME OF T-C-E CHARGED RUN #5= 9.893264
MOLES OF T-C-E CHARGED RUN #5= 0.110084

TABLE 21

CALCULATED DATA FOR DILUTION RUN #6

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.03	1.4570	1.4358	-0.0251	-0.0159	0.07486	0.00083	0.00083	0.99255	-0.0251	-0.0001	-0.00146
2	0.21	0.2239	0.1784	0.1528	-0.0188	0.17188	0.00191	0.00274	0.97587	0.1277	0.00260	0.022891
3	0.26	-0.0249	0.0289	0.1568	-0.0111	0.20404	0.00227	0.00501	0.95678	0.2845	0.00525	0.045265
4	0.33	0.0217	-0.0911	0.1835	0.0047	0.25765	0.00286	0.00788	0.93372	0.4680	0.00823	0.069239
5	0.27	0.0318	0.0866	0.1258	-0.0316	0.21392	0.00238	0.01026	0.91540	0.5938	0.01111	0.091618
6	0.34	0.0699	0.1054	0.1516	-0.0037	0.26984	0.00300	0.01326	0.89329	0.7454	0.01331	0.107065
7	0.46	-0.0128	-0.1338	0.2624	-0.0315	0.35827	0.00398	0.01725	0.86553	1.0078	0.01846	0.143922
8	0.40	-0.0362	0.1008	0.0261	-0.0252	0.31495	0.00350	0.02075	0.84252	1.0339	0.01883	0.142897
9	0.56	-0.0658	-0.0653	0.2886	-0.0115	0.43700	0.00486	0.02561	0.81255	1.3225	0.02371	0.173493
10	0.53	0.0566	-0.0029	0.0922	-0.0418	0.41674	0.00463	0.03025	0.78588	1.4147	0.02590	0.183307
11	0.36	-0.1027	-0.1535	0.1361	-0.0419	0.27788	0.00309	0.03334	0.76906	1.5508	0.02832	0.196142
12	0.32	0.0427	0.1582	0.0724	-0.0176	0.25461	0.00283	0.03618	0.75426	1.6232	0.02917	0.198133
13	0.34	-0.0436	-0.1223	0.0967	-0.0369	0.26379	0.00293	0.03911	0.73952	1.7199	0.03123	0.207960
14	0.34	0.1069	0.1189	0.0254	-0.0032	0.27074	0.00301	0.04213	0.72497	1.7453	0.03107	0.202869
15	0.60	-0.1722	-0.1077	0.1471	-0.0507	0.46574	0.00518	0.04731	0.70125	1.8924	0.03453	0.218078
16	0.42	-0.0490	-0.0509	0.0994	-0.0172	0.32772	0.00364	0.05095	0.68547	1.9918	0.03572	0.220502
17	0.34	-0.0508	-0.0463	0.0424	-0.0400	0.26497	0.00294	0.05390	0.67321	2.0342	0.03687	0.223512
18	0.59	0.2391	0.1338	0.0783	-0.0174	0.46948	0.00522	0.05913	0.65255	2.1125	0.03787	0.222546
19	0.48	-0.1832	-0.0878	0.0605	-0.0325	0.37176	0.00413	0.06326	0.63706	2.1730	0.03922	0.225012
20	0.56	0.1194	-0.0331	0.0315	-0.0124	0.44086	0.00490	0.06817	0.61963	2.2045	0.03939	0.219817
21	0.74	-0.0925	-0.0421	0.1412	-0.0535	0.57815	0.00643	0.07460	0.59816	2.3457	0.04264	0.229681
22	0.48	0.1446	0.1292	0.0533	-0.0284	0.38132	0.00424	0.07885	0.58479	2.3990	0.04317	0.227344
23	0.52	-0.0967	0.0644	0.0333	-0.0303	0.40737	0.00453	0.08338	0.57116	2.4323	0.04374	0.224960
24	0.36	0.0949	0.1996	0.0235	-0.0254	0.28765	0.00320	0.08658	0.56191	2.4558	0.04410	0.223190
25	0.80	-0.2821	-0.2285	0.1112	-0.0434	0.61855	0.00688	0.09346	0.54300	2.5670	0.04697	0.226727
26	0.43	0.1726	-0.0682	0.0924	-0.0271	0.33919	0.00377	0.09724	0.53316	2.6594	0.04775	0.229254
27	0.43	0.0116	0.0529	0.0149	-0.0118	0.33848	0.00376	0.10100	0.52369	2.6743	0.04779	0.225110
28	0.54	0.0543	0.0918	0.0075	-0.0266	0.42623	0.00474	0.10575	0.51224	2.6818	0.04816	0.222175
29	0.53	-0.1075	-0.1307	0.0024	-0.0290	0.41156	0.00457	0.11032	0.50164	2.6842	0.04823	0.217896
30	0.32	0.0892	0.0022	0.1309	-0.0314	0.25266	0.00281	0.11314	0.49535	2.8151	0.05055	0.225506
31	0.34	-0.0662	-0.0232	-0.0171	-0.0352	0.26515	0.00295	0.11609	0.48892	2.7980	0.05035	0.221691
32	0.67	-0.1977	-0.1612	0.0908	-0.0275	0.51926	0.00577	0.12186	0.47679	2.8888	0.05180	0.222408
33	0.66	0.2662	0.2235	-0.0052	-0.0560	0.52647	0.00585	0.12772	0.46509	2.8836	0.05223	0.218755
34	0.48	0.0556	-0.2282	-0.0032	-0.0196	0.37350	0.00415	0.13188	0.45713	2.8804	0.05152	0.212086

TABLE 21

CALCULATED DATA FOR DILUTION RUN #6 (CONTINUED)

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Vø	DEL Vøm (P CORR)
35	0.49	-0.1407	0.1464	0.0351	-0.0303	0.38452	0.00427	0.13616	0.44922	2.9155	0.05235	0.211762
36	0.63	0.1493	0.0890	0.0113	-0.0477	0.49847	0.00554	0.14170	0.43936	2.9268	0.05285	0.209123

VOLUME OF BENZENE CHARGED RUN #4= 9.92877
MOLES OF BENZENE CHARGED RUN #4= 0.11105

TABLE 22

CALCULATED DATA FOR RUN #7

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Vm	DEL Vm (P CORR)
1	0.31	-3.7892	-3.8295	0.0593	-0.0122	0.10800	0.00118	0.00118	0.98946	0.0593	0.00126	0.011243
2	0.21	0.3426	0.5018	0.1534	-0.0433	0.17973	0.00198	0.00317	0.97240	0.2127	0.00454	0.039556
3	0.47	-0.3493	-0.6192	0.2198	-0.0263	0.35153	0.00387	0.00704	0.94069	0.4325	0.00815	0.068638
4	0.25	0.2524	0.3850	0.1676	-0.0247	0.20744	0.00228	0.00932	0.92292	0.6001	0.01109	0.091668
5	0.35	0.1121	-0.0661	0.1208	0.0024	0.27539	0.00303	0.01236	0.90036	0.7209	0.01276	0.102890
6	0.37	0.0264	0.0363	0.1430	-0.0358	0.29138	0.00321	0.01557	0.87765	0.8639	0.01596	0.125420
7	0.30	0.0036	-0.1148	0.1323	-0.0088	0.23338	0.00257	0.01814	0.86027	0.9962	0.01782	0.137265

VOL. BENZENE CHARGED RUN #7= 10.04766
MOL BENZENE CHARGED RUN #7= 0.11171

TABLE 23

CALCULATED DATA FOR RUN #8

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.20	0.5917	0.6593	0.0334	-0.0806	0.17910	0.00197	0.00197	0.98236	0.0334	0.00202	0.018107
2	0.17	0.9337	0.8433	0.1944	0.0368	0.16489	0.00181	0.00378	0.96666	0.2278	0.00339	0.029840
3	0.40	0.0355	0.0512	0.1291	-0.0787	0.31534	0.00347	0.00726	0.93800	0.3569	0.00771	0.065861
4	0.96	-0.0669	-0.0561	0.5057	0.0020	0.75095	0.00827	0.01553	0.87615	0.8626	0.01528	0.121829
5	0.62	-1.4580	-1.8264	0.1489	-0.0593	0.42811	0.00471	0.02025	0.84440	1.0115	0.01902	0.146167
6	0.33	1.1890	1.5515	0.1470	-0.0172	0.30752	0.00338	0.02364	0.82298	1.1585	0.02088	0.156412
7	0.42	-0.0097	-0.0217	0.1465	-0.0269	0.32904	0.00362	0.02726	0.80123	1.3050	0.02367	0.172557
8	0.33	0.3173	0.3101	0.1075	-0.0291	0.27002	0.00297	0.03024	0.78423	1.4125	0.02562	0.182830
9	0.60	-0.4438	-0.7532	0.1111	-0.0525	0.44946	0.00495	0.03519	0.75746	1.5236	0.02798	0.192822
10	1.13	0.2023	0.2009	0.2222	-0.0739	0.89366	0.00984	0.04503	0.70934	1.7458	0.03221	0.207877
11	0.22	0.3339	0.6718	0.1349	0.0236	0.19044	0.00209	0.04713	0.69986	1.8807	0.03300	0.210163
12	0.57	0.1224	0.0689	0.1380	-0.0170	0.45057	0.00496	0.05210	0.67842	2.0187	0.03623	0.223691
13	0.38	0.1181	-0.0678	0.0152	-0.0316	0.29900	0.00329	0.05539	0.66490	2.0339	0.03666	0.221816
14	0.75	-0.0492	0.0291	0.1162	-0.0719	0.58803	0.00647	0.06187	0.63982	2.1501	0.03945	0.229647
15	0.56	-0.3801	-0.5346	0.0359	-0.0588	0.42487	0.00468	0.06655	0.62285	2.1860	0.03986	0.225917
16	0.49	0.3368	0.5597	0.1359	0.0076	0.40032	0.00441	0.07096	0.60767	2.3219	0.04112	0.227378
17	0.56	0.0505	0.1528	0.0302	-0.0351	0.44294	0.00487	0.07584	0.59170	2.3521	0.04243	0.228442
18	0.56	-0.2133	-0.1861	0.0480	-0.0411	0.43224	0.00476	0.08060	0.57691	2.4001	0.04332	0.227400
19	0.69	-0.0091	-0.3386	0.0606	-0.0537	0.53514	0.00589	0.08650	0.55960	2.4607	0.04464	0.227320
20	0.72	-0.6588	-0.9130	0.0875	-0.0305	0.53695	0.00591	0.09241	0.54324	2.5482	0.04579	0.226353
21	0.38	0.6189	1.1854	0.0233	0.0090	0.33014	0.00363	0.09605	0.53364	2.5715	0.04550	0.220952
22	0.60	0.1596	0.2269	0.0508	-0.0589	0.47757	0.00526	0.10131	0.52035	2.6223	0.04760	0.225374
23	0.48	-0.2000	-0.2928	0.0617	-0.0079	0.36782	0.00405	0.10536	0.51056	2.6840	0.04782	0.222143
24	0.74	0.0054	-0.0315	0.0429	-0.0285	0.58008	0.00639	0.11175	0.49584	2.7269	0.04893	0.220775
25	0.41	0.2155	0.3650	0.0738	-0.0552	0.33195	0.00365	0.11541	0.48779	2.8007	0.05080	0.225453
26	0.55	0.0543	0.0219	-0.0145	-0.0262	0.43283	0.00476	0.12018	0.47768	2.7862	0.04995	0.217090
27	0.58	-0.0340	-0.1051	0.0562	-0.0421	0.45255	0.00498	0.12516	0.46755	2.8424	0.05128	0.218141
28	0.58	-0.2783	-0.5272	0.0151	-0.0756	0.44072	0.00485	0.13002	0.45809	2.8575	0.05203	0.216851
29	0.78	0.2827	0.4541	0.0460	-0.0325	0.62500	0.00688	0.13691	0.44531	2.9035	0.05210	0.211119
30	0.72	-0.1392	-0.4794	0.0114	-0.0460	0.55397	0.00610	0.14301	0.43456	2.9149	0.05258	0.207914

VOL. BENZENE CHARGED RUN #8= 9.88650
MOL BENZENE CHARGED RUN #8= 0.10991

TABLE 24

CALCULATED DATA FOR RUN #11

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.21	0.6415	0.6560	0.0802	-0.0107	0.18777	0.00208	0.00208	0.01822	0.0802	0.00161	0.014099
2	0.28	0.3753	0.3611	0.1047	-0.0113	0.23273	0.00258	0.00467	0.03991	0.1849	0.00348	0.029752
3	0.51	-0.3299	-0.3313	0.1802	-0.0363	0.38837	0.00431	0.00899	0.07405	0.3651	0.00713	0.058777
4	0.62	0.2113	0.1870	0.1469	-0.0324	0.49346	0.00548	0.01447	0.11408	0.5120	0.00967	0.076202
5	0.89	-0.1658	-0.1746	0.2799	-0.0518	0.69218	0.00769	0.02217	0.16472	0.7919	0.01499	0.111401
6	0.54	0.0199	-0.0098	0.1084	-0.0353	0.42381	0.00471	0.02688	0.19297	0.9003	0.01663	0.119386
7	0.45	0.1927	0.1846	0.1317	-0.0069	0.35972	0.00399	0.03088	0.21549	1.0320	0.01847	0.128906
8	0.54	0.1204	0.1482	0.1036	-0.0580	0.42840	0.00476	0.03564	0.24072	1.1356	0.02117	0.142961
9	0.47	0.0316	0.0573	0.1361	-0.0387	0.37030	0.00411	0.03976	0.26126	1.2717	0.02317	0.152271
10	0.56	-0.0288	-0.0022	0.1336	-0.0383	0.43878	0.00487	0.04464	0.28420	1.4053	0.02566	0.163410
11	0.69	0.0030	-0.0021	0.1252	-0.0193	0.54133	0.00601	0.05066	0.31061	1.5305	0.02748	0.168535
12	0.43	0.1637	0.1592	0.1248	-0.0312	0.34307	0.00381	0.05447	0.32637	1.6553	0.02996	0.179547
13	0.66	-0.1462	-0.0768	0.0959	-0.0561	0.51382	0.00571	0.06018	0.34868	1.7512	0.03206	0.185762
14	0.58	0.1120	0.0283	0.1263	-0.0469	0.45750	0.00508	0.06527	0.36730	1.8775	0.03419	0.192394
15	0.72	-0.4490	-0.6057	0.1569	-0.0178	0.54613	0.00607	0.07134	0.38820	2.0344	0.03637	0.197912
16	0.36	0.4162	0.5468	0.0327	-0.0550	0.29951	0.00332	0.07467	0.39909	2.0671	0.03762	0.201064
17	0.56	-0.1119	0.0044	0.1565	0.0034	0.43742	0.00486	0.07954	0.41431	2.2236	0.03947	0.205634
18	0.43	0.2285	0.1207	0.0574	-0.0253	0.34353	0.00381	0.08335	0.42574	2.2810	0.04096	0.209205
19	0.55	-0.0891	-0.0068	0.0677	-0.0487	0.42978	0.00477	0.08813	0.43942	2.3487	0.04256	0.212224
20	0.54	-0.0709	-0.0871	0.1322	-0.0238	0.42083	0.00467	0.09281	0.45220	2.4809	0.04449	0.216756
21	0.93	-0.2454	-0.3879	0.1423	-0.0546	0.71836	0.00798	0.10080	0.47271	2.6232	0.04756	0.223048
22	0.46	0.3392	0.4243	0.0684	-0.0315	0.37442	0.00416	0.10496	0.48281	2.6916	0.04836	0.222469
23	0.64	-0.3336	-0.4598	0.0785	-0.0392	0.48801	0.00542	0.11039	0.49540	2.7701	0.04987	0.223810
24	1.04	-0.2528	-0.3890	0.1504	-0.0491	0.80451	0.00894	0.11933	0.51487	2.9205	0.05275	0.227605
25	0.84	0.1691	0.2783	0.1390	-0.0577	0.66693	0.00741	0.12675	0.52991	3.0595	0.05536	0.231456
26	0.70	0.2743	0.3591	0.0760	-0.0466	0.56040	0.00623	0.13298	0.54185	3.1355	0.05651	0.230265
27	0.66	-0.2408	-0.2251	0.0925	-0.0275	0.50951	0.00566	0.13864	0.55218	3.2280	0.05779	0.230163

VOL. T-C-E CHARGED RUN #11= 10.20606
MOL T-C-E CHARGED RUN #11= 0.11244

TABLE 25

CALCULATED DATA FOR DILUTION RUN #14

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.55	-3.0148	-3.3556	0.2630	-0.0161	0.31843	0.00346	0.00346	0.96969	0.2630	0.00496	0.043416
2	0.23	0.4857	0.6909	0.1271	-0.0349	0.20132	0.00213	0.00565	0.95147	0.3901	0.00755	0.064820
3	0.49	0.1206	-0.0735	0.2357	-0.0463	0.38524	0.00419	0.00984	0.91843	0.6258	0.01194	0.098947
4	0.44	0.0644	0.0849	0.2039	-0.0095	0.34783	0.00378	0.01363	0.89052	0.8297	0.01494	0.119882
5.1	0.36	0.0153	-0.0120	0.1152	-0.0267	0.28248	0.00307	0.01670	0.86906	0.9449	0.01728	0.135436
5.2												
6	0.64	-3.5625	-3.7481	0.1317	-0.0493	0.37236	0.00405	0.02076	0.84232	1.0766	0.02001	0.151976
7	0.35	0.0333	-0.1243	0.1471	-0.0274	0.27296	0.00297	0.02373	0.82373	1.2237	0.02224	0.165190
8	0.62	-0.0085	0.0508	0.1858	-0.0273	0.48715	0.00530	0.02903	0.79252	1.4095	0.0255E	?.182708
9	0.58	0.0869	0.0450	0.1317	-0.0325	0.45736	0.00497	0.03401	0.76530	1.5412	0.02800	0.193252
10	0.61	-0.0552	-0.0374	0.0918	-0.0326	0.47691	0.00519	0.03920	0.73884	1.6330	0.02962	0.197315
11	0.76	0.0392	-0.1243	0.1403	-0.0620	0.59472	0.00647	0.04567	0.70830	1.7733	0.03262	0.208375
12	0.78	0.0213	0.2073	0.1264	-0.0453	0.61598	0.00670	0.05238	0.67922	1.8997	0.03457	0.211747
13	0.68	0.0337	0.0428	0.1016	-0.0694	0.53483	0.00582	0.05820	0.65584	2.0013	0.03677	0.217483
14	0.70	-0.0474	-0.1567	0.0853	-0.0094	0.54554	0.00593	0.06413	0.63360	2.0866	0.03720	0.212533
15	0.68	0.0459	0.1146	0.1069	-0.0384	0.53632	0.00583	0.06997	0.61315	2.1935	0.03968	0.219382
16	0.93	-0.0753	-0.1316	0.0979	-0.0637	0.72593	0.00790	0.07787	0.58749	2.2914	0.04185	0.221691
17	1.10	0.1074	0.0917	0.0677	-0.0650	0.86650	0.00943	0.08730	0.55954	2.3591	0.04308	0.217339
18	1.32	0.0146	0.1167	0.1147	-0.0595	1.03789	0.01129	0.09860	0.52937	2.4738	0.04498	0.214724
19	0.81	0.0017	-0.0659	0.0573	-0.0463	0.63432	0.00690	0.10550	0.51248	2.5311	0.04580	0.211640
20	0.95	-0.0362	0.0380	0.0412	-0.1043	0.74532	0.00811	0.11361	0.49397	2.5723	0.04753	0.211692
21	0.81	-0.0871	-0.0059	0.0508	-0.0488	0.63381	0.00689	0.12051	0.47925	2.6231	0.04746	0.205073
22	1.11	-0.1924	-0.2305	0.0376	-0.0885	0.86331	0.00939	0.12991	0.46055	2.6607	0.04883	0.202780
23	1.16	0.0842	0.0055	0.0594	0.0008	0.91163	0.00992	0.13983	0.44232	2.7201	0.04831	0.192670

VOL. BENZENE CHARGED RUN #14= 10.10079
MOL BENZENE CHARGED RUN #14= 0.11091

TABLE 26

CALCULATED DATA FOR RUN #15

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.55	-0.4936	-0.5012	0.1969	-0.0391	0.41383	0.00454	0.00454	0.03989	0.1969	0.00419	0.0368
2	0.54	0.6700	0.6649	0.0771	-0.0139	0.44732	0.00491	0.00945	0.07958	0.2740	0.00511	0.0430
3	0.66	0.1421	0.1338	0.2213	-0.0638	0.52267	0.00573	0.01519	0.12199	0.4953	0.00994	0.0798
4	0.52	-0.0024	-0.0038	0.1136	-0.0406	0.40784	0.00447	0.01967	0.15247	0.6089	0.01154	0.0895
5	0.52	0.0280	0.2674	0.1378	-0.0386	0.41319	0.00459	0.02421	0.18126	0.7467	0.01394	0.1044
6	0.75	0.0187	-0.2350	0.1784	-0.0287	0.58454	0.00641	0.03062	0.21880	0.9251	0.01692	0.1209
7	1.02	-0.0770	-0.0779	0.2125	-0.0381	0.79746	0.00875	0.03938	0.26479	1.1376	0.02085	0.1402
8	1.42	-0.7536	-0.7994	0.2864	-0.1020	1.08645	0.01193	0.05131	0.31938	1.4240	0.02708	0.1686
9	0.50	1.0041	1.0593	0.1415	-0.0367	0.42887	0.00470	0.05602	0.33876	1.5655	0.02847	0.1722
10	0.81	-0.0477	-0.0388	0.1341	-0.0440	0.63992	0.00696	0.06298	0.36546	1.6996	0.03095	0.1796
11	0.83	0.0602	0.0510	0.1440	-0.0879	0.65312	0.00717	0.07015	0.39081	1.8436	0.03428	0.1910
12	0.84	-0.0388	-0.0308	0.1437	-0.0296	0.65776	0.00722	0.07738	0.41438	1.9873	0.03585	0.1920

VOL. T-C-E CHARGED RUN #15= 10.04795
MOL T-C-E CHARGED RUN #15= 0.10936

TABLE 27

CALCULATED DATA FOR RUN #16

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	6.60	-0.4373	-0.4794	1.5779	-0.3855	5.16156	0.05667	0.05667	0.33905	1.5779	0.03488	0.2087
2	0.70	1.6742	1.6978	0.1316	-0.0601	0.60900	0.00668	0.06336	0.36447	1.7095	0.03141	0.1807
3	0.93	0.0392	0.0398	0.1851	-0.0425	0.73100	0.00802	0.07139	0.39252	1.8946	0.03440	0.1892
4	0.95	0.0487	0.0300	0.1585	-0.0568	0.74669	0.00819	0.07959	0.41873	2.0531	0.03746	0.1971
5	1.10	-0.2363	0.1029	0.1759	-0.0605	0.86060	0.00945	0.08904	0.44626	2.2290	0.04066	0.2038
6	0.93	0.2428	-0.0991	0.1100	-0.0491	0.73214	0.00803	0.09708	0.46770	2.3390	0.04235	0.2041
7	1.23	0.0040	0.0092	0.1866	-0.0901	0.96519	0.01059	0.10767	0.49356	2.5256	0.04640	0.2127
8	1.03	0.1171	0.1134	0.1550	-0.0569	0.81214	0.00891	0.11659	0.51345	2.6806	0.04860	0.2141
9	1.20	0.0343	-0.1401	0.1635	-0.0655	0.93954	0.01031	0.12691	0.53460	2.8441	0.05166	0.2176

VOL. BENZENE CHARGED RUN #16= 10.15151
MOL BENZENE CHARGED RUN #16= 0.11049

TABLE 28

CALCULATED DATA FOR DILUTION RUN #17

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vc	DEL nc	nc TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.27	3.0172	3.0769	0.2727	-0.0324	0.31996	0.00361	0.00361	0.96909	0.2727	0.00541	0.046331
2	0.35	-0.0267	-0.0195	0.2417	-0.0258	0.27376	0.00308	0.00669	0.94413	0.5144	0.00958	0.079928
3	0.72	-0.1307	-0.1320	0.3345	-0.0392	0.56019	0.00632	0.01301	0.89686	0.8489	0.01575	0.124785
4	0.92	0.1427	0.1253	0.3704	-0.0597	0.72651	0.00819	0.02121	0.84217	1.2193	0.02257	0.167942
5	1.10	0.0003	0.0141	0.3206	-0.0570	0.86322	0.00973	0.03095	0.78528	1.5399	0.02834	0.196586
6	0.74	-0.1268	-0.1305	0.2723	-0.1027	0.57597	0.00649	0.03745	0.75141	1.8122	0.03397	0.225508
7	1.10	-0.0231	-0.0169	0.3345	-0.0109	0.86226	0.00972	0.04718	0.70583	2.1467	0.03827	0.238624
8	0.99	0.0686	0.0585	0.1844	-0.0703	0.77893	0.00878	0.05597	0.66917	2.3311	0.04259	0.251752
9	0.86	0.0137	0.0186	0.2047	-0.0785	0.67526	0.00761	0.06359	0.64033	2.5358	0.04640	0.262429
10	1.07	-0.0024	-0.0044	0.3618	-0.0505	0.83931	0.00947	0.07306	0.60778	2.8976	0.05232	0.280883
11	0.82	0.2137	0.2019	0.0260	-0.0956	0.65068	0.00734	0.08040	0.58473	2.9236	0.05358	0.276751
12	1.01	-0.1408	-0.1259	0.0771	-0.0445	0.78763	0.00888	0.08929	0.55907	3.0007	0.05401	0.266720
13	1.08	-0.1091	-0.1096	0.0773	-0.0598	0.84340	0.00951	0.09880	0.53398	3.0780	0.05568	0.262618
14	0.84	0.0892	0.0892	0.0339	-0.0598	0.66216	0.00747	0.10627	0.51580	3.1119	0.05630	0.256511
15	1.42	-0.0304	-0.0365	0.0731	-0.0794	1.11283	0.01255	0.11883	0.48789	3.1850	0.05791	0.249555
16	1.17	0.0332	0.0285	0.0596	-0.0556	0.91898	0.01036	0.12920	0.46703	3.2446	0.05854	0.241488
17	1.30	0.0180	0.0182	0.0682	-0.0879	1.02051	0.01151	0.14071	0.44585	3.3128	0.06034	0.237624
18	1.31	-0.0304	-0.0239	0.0680	-0.1000	1.02675	0.01158	0.15230	0.42639	3.3808	0.06177	0.232665

VOL. BENZENE CHARGED RUN #17= 9.94220
MOL BENZENE CHARGED RUN #17= 0.11322

TABLE 29

CALCULATED DATA FOR DILUTION RUN #18

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	0.18	1.5702	1.5610	0.0685	0.0099	0.19677	0.00224	0.00224	0.01949	0.0685	0.00104	0.009062
2	0.54	0.0986	0.1069	0.1332	-0.0587	0.42728	0.00486	0.00710	0.05931	0.2017	0.00462	0.038634
3	0.47	-0.0701	-0.0852	0.2305	-0.0380	0.36596	0.00416	0.01127	0.09092	0.4322	0.00835	0.067418
4	0.49	0.1274	-0.0428	0.1605	-0.0507	0.38591	0.00439	0.01566	0.12204	0.5927	0.01143	0.089058
5	0.66	-0.1288	-0.0259	0.2105	0.0012	0.51503	0.00586	0.02153	0.16040	0.8032	0.01427	0.106305
6	0.75	-0.0110	-0.0100	0.2141	-0.0302	0.58801	0.00669	0.02823	0.20029	1.0173	0.01861	0.132095
7	0.73	-0.0601	0.0552	0.2037	-0.0557	0.57261	0.00652	0.03475	0.23565	1.2210	0.02268	0.153801
8	0.67	0.0093	0.0487	0.2070	-0.0205	0.52665	0.00599	0.04074	0.26552	1.4280	0.02575	0.167796
9	0.86	0.1416	-0.0131	0.1796	-0.0585	0.67696	0.00770	0.04845	0.30065	1.6076	0.02962	0.183785
10	0.94	-0.2201	-0.1466	0.2380	-0.0562	0.73094	0.00832	0.05678	0.33499	1.8456	0.03378	0.199330
11	1.14	0.0745	0.0978	0.2410	-0.0775	0.89741	0.01021	0.06700	0.37281	2.0866	0.03845	0.213978

VOL. T-C-E CHARGED RUN #18= 9.98975
MOL T-C-E CHARGED RUN #18= 0.11272

TABLE 30

CALCULATED DATA FOR DILUTION RUN #19

TILT	DEL B	DEL C1	DEL C2	DEL C	DEL A	DEL Vb	DEL nb	nb TOT	x (BENZ)	C TOT	DEL Ve	DEL Vem (P CORR)
1	4.50	3.0837	3.0672	2.0327	-0.3007	3.63948	0.04144	0.04144	0.26884	2.0327	0.04144	0.268842
2	1.78	-1.5670	-1.5605	0.3317	-0.0925	1.34094	0.01527	0.05671	0.33474	2.3644	0.04366	0.257697
3	0.74	-0.1418	-0.1501	-0.0542	-0.0493	0.57536	0.00655	0.06326	0.35951	2.3102	0.04193	0.238313
4	0.52	0.2966	0.2061	-0.0406	-0.0246	0.41686	0.00474	0.06801	0.37633	2.2696	0.04092	0.226459
5	1.13	1.2013	1.2984	0.0802	-0.0708	0.93086	0.01060	0.07861	0.41088	2.3498	0.04302	0.224887
6	1.70	-1.6625	-1.6562	0.2653	-0.1058	1.27479	0.01451	0.09313	0.45243	2.6151	0.04826	0.234490
7	0.80	-0.1673	-0.1638	0.1448	-0.0397	0.62174	0.00708	0.10021	0.47064	2.7599	0.04969	0.233374
8	1.29	0.0351	0.0257	0.2128	-0.0785	1.01310	0.01153	0.11175	0.49784	2.9727	0.05411	0.241076
9	1.42	0.0022	0.0100	0.2074	-0.0895	1.11423	0.01268	0.12443	0.52471	3.1801	0.05802	0.244675

VOL. T-C-E CHARGED RUN #19= 10.01291
MOL. T-C-E CHARGED RUN #19= 0.11298

APPENDIX C-2

MAIN FRAME COMPUTER GENERATED DATA

How many curve fitting constants do you want?
(must be between 2 and 5)
4

What is the name of the data file to be used?
bzcyclo

(Data must be stored in x,y pairs with format f7.6,1x,f7.6.
The first line of the file must contain the number
of data points in the file, with format I3)

gamma 1 = 2.60920
gamma 2 = 0.15423
gamma 3 = 0.12096
gamma 4 = -0.14836

x benzene	molar Ve	Ve fit	Error
0.982598D+00	0.488850D-01	0.462777D-01	0.270732D-02
0.973725D+00	0.683320D-01	0.690231D-01	-.691116D-03
0.958196D+00	0.108880D+00	0.107496D+00	0.138387D-02
0.952479D+00	0.116851D+00	0.121243D+00	-.439170D-02
0.943940D+00	0.139468D+00	0.141367D+00	-.189859D-02
0.864218D+00	0.303852D+00	0.307255D+00	-.340286D-02
0.856702D+00	0.319363D+00	0.320978D+00	-.161528D-02
0.844607D+00	0.340557D+00	0.342412D+00	-.185517D-02
0.820936D+00	0.385329D+00	0.382094D+00	0.323525D-02
0.815388D+00	0.385332D+00	0.390970D+00	-.563751D-02
0.803499D+00	0.409599D+00	0.409457D+00	0.142003D-03
0.747767D+00	0.491665D+00	0.486718D+00	0.494717D-02
0.736557D+00	0.503508D+00	0.500435D+00	0.307281D-02
0.723792D+00	0.517239D+00	0.515328D+00	0.191133D-02
0.714135D+00	0.531683D+00	0.526083D+00	0.560028D-02
0.708145D+00	0.532071D+00	0.532534D+00	-.462511D-03
0.681188D+00	0.564226D+00	0.559488D+00	0.473795D-02
0.674067D+00	0.565601D+00	0.566043D+00	-.442270D-03
0.654324D+00	0.583754D+00	0.582986D+00	0.767930D-03
0.648091D+00	0.585293D+00	0.587959D+00	-.266625D-02
0.644710D+00	0.588741D+00	0.590581D+00	-.184042D-02
0.639817D+00	0.595641D+00	0.594282D+00	0.135879D-02
0.636642D+00	0.598474D+00	0.596624D+00	0.184991D-02
0.624607D+00	0.606660D+00	0.605075D+00	0.158466D-02
0.618849D+00	0.607657D+00	0.608880D+00	-.122312D-02
0.611273D+00	0.613835D+00	0.613650D+00	0.184562D-03
0.605135D+00	0.613927D+00	0.617318D+00	-.339148D-02
0.598217D+00	0.622424D+00	0.621241D+00	0.118302D-02
0.590836D+00	0.625833D+00	0.625178D+00	0.654957D-03
0.585149D+00	0.627072D+00	0.628036D+00	-.964451D-03
0.579559D+00	0.630177D+00	0.630697D+00	-.520206D-03
0.570454D+00	0.638050D+00	0.634714D+00	0.333599D-02
0.564560D+00	0.632918D+00	0.637104D+00	-.418604D-02
0.556489D+00	0.642213D+00	0.640108D+00	0.210523D-02
0.551040D+00	0.641809D+00	0.641959D+00	-.150180D-03
0.543776D+00	0.646297D+00	0.644205D+00	0.209188D-02

x benzene	molar Ve	Ve fit	Error
0.537856D+00	0.648883D+00	0.645847D+00	0.303595D-02
0.521861D+00	0.649757D+00	0.649432D+00	0.325362D-03
0.515214D+00	0.652676D+00	0.650553D+00	0.212270D-02
0.505334D+00	0.648356D+00	0.651818D+00	-.346232D-02
0.496249D+00	0.651022D+00	0.652555D+00	-.153255D-02
0.489836D+00	0.648933D+00	0.652826D+00	-.389343D-02
0.482731D+00	0.653309D+00	0.652887D+00	0.422191D-03
0.475997D+00	0.650431D+00	0.652709D+00	-.227818D-02
0.172190D-01	0.471990D-01	0.463225D-01	0.876486D-03
0.361580D-01	0.959350D-01	0.954183D-01	0.516677D-03
0.494660D-01	0.125853D+00	0.128731D+00	-.287770D-02
0.747810D-01	0.183639D+00	0.189341D+00	-.570240D-02
0.877360D-01	0.220394D+00	0.218940D+00	0.145427D-02
0.104803D+00	0.262044D+00	0.256447D+00	0.559743D-02
0.120358D+00	0.287366D+00	0.289146D+00	-.178020D-02
0.130382D+00	0.313017D+00	0.309464D+00	0.355329D-02
0.179718D+00	0.400060D+00	0.400779D+00	-.718890D-03
0.190922D+00	0.418912D+00	0.419498D+00	-.586347D-03
0.211727D+00	0.452778D+00	0.452278D+00	0.500304D-03
0.224716D+00	0.474713D+00	0.471439D+00	0.327392D-02
0.230172D+00	0.482885D+00	0.480031D+00	0.285373D-02
0.242246D+00	0.493453D+00	0.495720D+00	-.226725D-02
0.250965D+00	0.508297D+00	0.507116D+00	0.118064D-02
0.260400D+00	0.520316D+00	0.518950D+00	0.136638D-02
0.272142D+00	0.537775D+00	0.532949D+00	0.482619D-02
0.280297D+00	0.538673D+00	0.542199D+00	-.352568D-02
0.289399D+00	0.549923D+00	0.552067D+00	-.214405D-02
0.299045D+00	0.560414D+00	0.562003D+00	-.158892D-02
0.308215D+00	0.568427D+00	0.570953D+00	-.252556D-02
0.316561D+00	0.573586D+00	0.578680D+00	-.509393D-02
0.324888D+00	0.584616D+00	0.585995D+00	-.137862D-02
0.330929D+00	0.587967D+00	0.591055D+00	-.308834D-02
0.339491D+00	0.594755D+00	0.597875D+00	-.312049D-02
0.344372D+00	0.600667D+00	0.601579D+00	-.912272D-03
0.352865D+00	0.604277D+00	0.607707D+00	-.342954D-02
0.383310D+00	0.622445D+00	0.626392D+00	-.394675D-02
0.388859D+00	0.624959D+00	0.629251D+00	-.429166D-02
0.396821D+00	0.636891D+00	0.633061D+00	0.382952D-02
0.404594D+00	0.637774D+00	0.636452D+00	0.132161D-02
0.412435D+00	0.641954D+00	0.639545D+00	0.240885D-02
0.418731D+00	0.639717D+00	0.641792D+00	-.207453D-02
0.426227D+00	0.645168D+00	0.644192D+00	0.975675D-03
0.433145D+00	0.647773D+00	0.646145D+00	0.162761D-02
0.439704D+00	0.648037D+00	0.647766D+00	0.271440D-03
0.449272D+00	0.650932D+00	0.649727D+00	0.120475D-02
0.453895D+00	0.648650D+00	0.650505D+00	-.185520D-02
0.461003D+00	0.652311D+00	0.651487D+00	0.824420D-03
0.466560D+00	0.653528D+00	0.652073D+00	0.145462D-02
0.473266D+00	0.653148D+00	0.652572D+00	0.576277D-03
0.477641D+00	0.651683D+00	0.652774D+00	-.109070D-02
0.483168D+00	0.656913D+00	0.652890D+00	0.402257D-02
0.490465D+00	0.653824D+00	0.652809D+00	0.101514D-02

x benzene	molar Ve	Ve fit	Error
0.495724D+00	0.656270D+00	0.652585D+00	0.368547D-02
0.504833D+00	0.651586D+00	0.651870D+00	-.283602D-03
0.510269D+00	0.654122D+00	0.651247D+00	0.287527D-02
0.516402D+00	0.650495D+00	0.650369D+00	0.126235D-03
0.522156D+00	0.653896D+00	0.649377D+00	0.451917D-02
0.529117D+00	0.648458D+00	0.647960D+00	0.497927D-03
0.534580D+00	0.646847D+00	0.646683D+00	0.164340D-03

The standard deviation for this set of fitting constants is: 0.275033D-02

The condition number for the A matrix is: 85.648

```
How many curve fitting constants do you want?
(must be between 2 and 5)

3


What is the name of the data file to be used?

(Data must be stored in x,y pairs with format f7.6,1x,f7.6.
 The first line of the file must contain the number
 of data points in the file, with format I3)

bztce10


gamma 1 =     1.01164
gamma 2 =    -0.41103
gamma 3 =     0.07189
```

x benzene	molar Ve	Ve fit	Error
0.969098D+00	0.463310D-01	0.437391D-01	0.259194D-02
0.944136D+00	0.799280D-01	0.756058D-01	0.432216D-02
0.896863D+00	0.124785D+00	0.127944D+00	-.315855D-02
0.842176D+00	0.167942D+00	0.176326D+00	-.838376D-02
0.785282D+00	0.196586D+00	0.214067D+00	-.174805D-01
0.751412D+00	0.225508D+00	0.230967D+00	-.545917D-02
0.705836D+00	0.238624D+00	0.247712D+00	-.908774D-02
0.669171D+00	0.251752D+00	0.256568D+00	-.481563D-02
0.640336D+00	0.262429D+00	0.260861D+00	0.156848D-02
0.607783D+00	0.280883D+00	0.263076D+00	0.178068D-01
0.584737D+00	0.276751D+00	0.263063D+00	0.136885D-01
0.559076D+00	0.266720D+00	0.261599D+00	0.512113D-02
0.533984D+00	0.262618D+00	0.258777D+00	0.384121D-02
0.524715D+00	0.244675D+00	0.257403D+00	-.127283D-01
0.515808D+00	0.256511D+00	0.255921D+00	0.589782D-03
0.497848D+00	0.241076D+00	0.252464D+00	-.113879D-01
0.487898D+00	0.249555D+00	0.250287D+00	-.732191D-03
0.470640D+00	0.233374D+00	0.246087D+00	-.127131D-01
0.467030D+00	0.241488D+00	0.245142D+00	-.365426D-02
0.452433D+00	0.234490D+00	0.241095D+00	-.660545D-02
0.445852D+00	0.237624D+00	0.239155D+00	-.153093D-02
0.426399D+00	0.232665D+00	0.233013D+00	-.347925D-03
0.410887D+00	0.224887D+00	0.227697D+00	-.281029D-02
0.376333D+00	0.226459D+00	0.214610D+00	0.118487D-01
0.372813D+00	0.213978D+00	0.213186D+00	0.792293D-03
0.334998D+00	0.199330D+00	0.196894D+00	0.243565D-02
0.300654D+00	0.183785D+00	0.180655D+00	0.312989D-02
0.265523D+00	0.167796D+00	0.162783D+00	0.501307D-02
0.235653D+00	0.153801D+00	0.146695D+00	0.710610D-02
0.200290D+00	0.132095D+00	0.126712D+00	0.538291D-02

x benzene	molar Ve	Ve fit	Error
0.160402D+00	0.106305D+00	0.103110D+00	0.319477D-02
0.122046D+00	0.890580D-01	0.795076D-01	0.955043D-02
0.909280D-01	0.674180D-01	0.598027D-01	0.761532D-02
0.593100D-01	0.386340D-01	0.393453D-01	-.711347D-03
0.194920D-01	0.906200D-02	0.130540D-01	-.399202D-02

The standard deviation for this set of fitting constants is: 0.801066D-02

The condition number for the A matrix is: 13.978

```
How many curve fitting constants do you want?
(must be between 2 and 5)
2

What is the name of the data file to be used?
bztce25

(Data must be stored in x,y pairs with format f7.6,1x,f7.6.
 The first line of the file must contain the number
 of data points in the file, with format I3)

gamma 1 =     0.87624
gamma 2 =    -0.23889
```

x benzene	molar Ve	Ve fit	Error
0.130100D-01	0.000000D+00	0.826384D-02	-.826384D-02
0.375440D-01	0.210740D-01	0.236784D-01	-.260440D-02
0.552100D-01	0.380340D-01	0.346212D-01	0.341279D-02
0.781140D-01	0.471800D-01	0.485845D-01	-.140445D-02
0.990450D-01	0.610230D-01	0.610966D-01	-.736056D-04
0.118296D+00	0.680540D-01	0.723719D-01	-.431786D-02
0.147299D+00	0.908370D-01	0.888917D-01	0.194530D-02
0.177641D+00	0.118168D+00	0.105506D+00	0.126624D-01
0.193107D+00	0.114801D+00	0.113686D+00	0.111536D-02
0.220874D+00	0.131596D+00	0.127841D+00	0.375509D-02
0.239233D+00	0.130895D+00	0.136801D+00	-.590568D-02
0.258803D+00	0.157255D+00	0.145978D+00	0.112769D-01
0.281750D+00	0.158838D+00	0.156220D+00	0.261808D-02
0.316878D+00	0.177559D+00	0.171519D+00	0.603964D-02
0.331399D+00	0.178200D+00	0.176303D+00	0.189710D-02
0.353390D+00	0.185219D+00	0.184219D+00	0.999671D-03
0.365173D+00	0.192248D+00	0.188198D+00	0.405011D-02
0.382314D+00	0.197648D+00	0.193646D+00	0.400228D-02
0.395771D+00	0.208861D+00	0.197632D+00	0.112289D-01
0.410579D+00	0.209543D+00	0.201714D+00	0.782888D-02
0.424761D+00	0.208402D+00	0.205316D+00	0.308582D-02
0.434473D+00	0.211411D+00	0.207605D+00	0.380591D-02
0.439369D+00	0.209123D+00	0.208703D+00	0.419812D-03
0.445434D+00	0.222848D+00	0.210011D+00	0.128370D-01
0.449227D+00	0.211762D+00	0.210799D+00	0.962966D-03
0.456927D+00	0.218809D+00	0.212328D+00	0.648140D-02
0.457139D+00	0.212086D+00	0.212368D+00	-.282321D-03
0.465095D+00	0.218755D+00	0.213843D+00	0.491153D-02
0.471376D+00	0.227651D+00	0.214934D+00	0.127168D-01
0.476792D+00	0.222408D+00	0.215822D+00	0.658610D-02
0.488142D+00	0.224192D+00	0.217521D+00	0.667082D-02
0.488920D+00	0.221691D+00	0.217630D+00	0.406140D-02
0.495354D+00	0.225506D+00	0.218486D+00	0.701983D-02
0.497926D+00	0.229954D+00	0.218808D+00	0.111455D-01
0.501645D+00	0.217896D+00	0.219254D+00	-.135810D-02
0.512241D+00	0.222175D+00	0.220390D+00	0.178505D-02
0.512382D+00	0.227093D+00	0.220404D+00	0.668929D-02
0.523697D+00	0.225110D+00	0.221392D+00	0.371792D-02
0.533166D+00	0.229254D+00	0.222040D+00	0.721376D-02

x benzene	molar Ve	Ve fit	Error
0.543005D+00	0.226727D+00	0.222538D+00	0.418879D-02
0.561915D+00	0.223130D+00	0.222983D+00	0.146963D-03
0.571165D+00	0.224960D+00	0.222950D+00	0.200953D-02
0.584798D+00	0.227344D+00	0.222597D+00	0.474736D-02
0.598163D+00	0.229681D+00	0.221890D+00	0.779121D-02
0.619633D+00	0.219817D+00	0.219991D+00	-.173802D-03
0.637069D+00	0.225012D+00	0.217739D+00	0.727281D-02
0.652554D+00	0.222546D+00	0.215193D+00	0.735285D-02
0.673219D+00	0.223512D+00	0.210976D+00	0.125364D-01
0.685470D+00	0.220502D+00	0.208023D+00	0.124785D-01
0.701254D+00	0.218078D+00	0.203714D+00	0.143642D-01
0.724978D+00	0.202869D+00	0.196141D+00	0.672795D-02
0.739521D+00	0.207960D+00	0.190834D+00	0.171258D-01
0.754263D+00	0.198133D+00	0.184928D+00	0.132048D-01
0.769061D+00	0.196142D+00	0.178457D+00	0.176846D-01
0.785889D+00	0.183307D+00	0.170427D+00	0.128801D-01
0.812552D+00	0.173493D+00	0.156206D+00	0.172868D-01
0.842527D+00	0.142897D+00	0.137968D+00	0.492884D-02
0.865539D+00	0.143922D+00	0.122304D+00	0.216183D-01
0.893294D+00	0.107065D+00	0.101435D+00	0.563046D-02
0.915402D+00	0.916180D-01	0.832270D-01	0.839102D-02
0.933722D+00	0.692390D-01	0.670505D-01	0.218851D-02
0.956785D+00	0.452850D-01	0.452542D-01	0.308494D-04
0.975873D+00	0.228910D-01	0.259842D-01	-.309324D-02
0.992554D+00	0.000000D+00	0.821515D-02	-.821515D-02

The standard deviation for this set of fitting constants is: 0.8254980-02

The condition number for the A matrix is: 3.536

```
How many curve fitting constants do you want?
(must be between 2 and 5)
4

What is the name of the data file to be used?

(Data must be stored in x,y pairs with format f7.6,1x,f7.6.
 The first line of the file must contain the number
 of data points in the file, with format I3)

bztce30

gamma 1 =     0.89426
gamma 2 =    -0.30734
gamma 3 =     0.10541
gamma 4 =     0.13159
```

x benzene	molar Ve	Ve fit	Error
0.989460D+00	0.112430D-01	0.122299D-01	-.986934D-03
0.982364D+00	0.181070D-01	0.202826D-01	-.217564D-02
0.972405D+00	0.395560D-01	0.313350D-01	0.822104D-02
0.966669D+00	0.298400D-01	0.375670D-01	-.772700D-02
0.940691D+00	0.686380D-01	0.645471D-01	0.409092D-02
0.938009D+00	0.658610D-01	0.672150D-01	-.135402D-02
0.922929D+00	0.916680D-01	0.818014D-01	0.986656D-02
0.900360D+00	0.102890D+00	0.102306D+00	0.584055D-03
0.877652D+00	0.125420D+00	0.121320D+00	0.409986D-02
0.876150D+00	0.121829D+00	0.122520D+00	-.691479D-03
0.860273D+00	0.137265D+00	0.134774D+00	0.249123D-02
0.844404D+00	0.146167D+00	0.146228D+00	-.612595D-04
0.822984D+00	0.156412D+00	0.160440D+00	-.402815D-02
0.801236D+00	0.172557D+00	0.173416D+00	-.859403D-03
0.784230D+00	0.182830D+00	0.182558D+00	0.272153D-03
0.757469D+00	0.192822D+00	0.195193D+00	-.237056D-02
0.709341D+00	0.207877D+00	0.212724D+00	-.484723D-02
0.699865D+00	0.210163D+00	0.215421D+00	-.525827D-02
0.678422D+00	0.223631D+00	0.220648D+00	0.298347D-02
0.664903D+00	0.221816D+00	0.223335D+00	-.151867D-02
0.639829D+00	0.229647D+00	0.227124D+00	0.252302D-02
0.622858D+00	0.225917D+00	0.228843D+00	-.292620D-02
0.607671D+00	0.227378D+00	0.229829D+00	-.245051D-02
0.591708D+00	0.228442D+00	0.230323D+00	-.188125D-02
0.576918D+00	0.227400D+00	0.230307D+00	-.290651D-02
0.559602D+00	0.227320D+00	0.229731D+00	-.241139D-02
0.552187D+00	0.230163D+00	0.229309D+00	0.854281D-03
0.543240D+00	0.226353D+00	0.228663D+00	-.230954D-02
0.541851D+00	0.230265D+00	0.228549D+00	0.171589D-02
0.533647D+00	0.220952D+00	0.227809D+00	-.685657D-02
0.529917D+00	0.231456D+00	0.227433D+00	0.402348D-02
0.520355D+00	0.225374D+00	0.226359D+00	-.984671D-03
0.514879D+00	0.227605D+00	0.225674D+00	0.193107D-02
0.510561D+00	0.222143D+00	0.225099D+00	-.295591D-02
0.495842D+00	0.220775D+00	0.222912D+00	-.213748D-02

x benzene	molar Ve	Ve fit	Error
0.495406D+00	0.223810D+00	0.222842D+00	0.967507D-03
0.487794D+00	0.225453D+00	0.221573D+00	0.387963D-02
0.482813D+00	0.222469D+00	0.220695D+00	0.177372D-02
0.477685D+00	0.217090D+00	0.219753D+00	-.266269D-02
0.472717D+00	0.223048D+00	0.218803D+00	0.424519D-02
0.467554D+00	0.218141D+00	0.217778D+00	0.362953D-03
0.458093D+00	0.216851D+00	0.215803D+00	0.104806D-02
0.452200D+00	0.216756D+00	0.214511D+00	0.224542D-02
0.445314D+00	0.211119D+00	0.212942D+00	-.182257D-02
0.439422D+00	0.212224D+00	0.211550D+00	0.674260D-03
0.434569D+00	0.207914D+00	0.210370D+00	-.245588D-02
0.425742D+00	0.209205D+00	0.208148D+00	0.105690D-02
0.414317D+00	0.205634D+00	0.205131D+00	0.502708D-03
0.399096D+00	0.201064D+00	0.200874D+00	0.189559D-03
0.388208D+00	0.197912D+00	0.197670D+00	0.242495D-03
0.367306D+00	0.192394D+00	0.191161D+00	0.123294D-02
0.348663D+00	0.185762D+00	0.184980D+00	0.781984D-03
0.326372D+00	0.179547D+00	0.177148D+00	0.239902D-02
0.310619D+00	0.168535D+00	0.171334D+00	-.279929D-02
0.284206D+00	0.163410D+00	0.161084D+00	0.232599D-02
0.261264D+00	0.152271D+00	0.151677D+00	0.594324D-03
0.240727D+00	0.142961D+00	0.142855D+00	0.105565D-03
0.215495D+00	0.128906D+00	0.131484D+00	-.257825D-02
0.192976D+00	0.119386D+00	0.120812D+00	-.142642D-02
0.164728D+00	0.111401D+00	0.106668D+00	0.473318D-02
0.114082D+00	0.762020D-01	0.788673D-01	-.266533D-02
0.740570D-01	0.587770D-01	0.541921D-01	0.458487D-02
0.399180D-01	0.297520D-01	0.307834D-01	-.103136D-02
0.182280D-01	0.140990D-01	0.145618D-01	-.462826D-03

The standard deviation for this set of fitting constants is: 0.324163D-02

The condition number for the A matrix is: 102.370

```
How many curve fitting constants do you want?
(must be between 2 and 5)
5

What is the name of the data file to be used?

(Data must be stored in x,y pairs with format f7.6,1x,f7.6.
 The first line of the file must contain the number
 of data points in the file, with format I3)

bztce40

gamma 1 =     0.85454
gamma 2 =    -0.33061
gamma 3 =    -0.05882
gamma 4 =     0.00471
gamma 5 =     0.46645
```

x benzene	molar Ve	Ve fit	Error
0.969839D+00	0.434160D-01	0.432678D-01	0.148242D-03
0.951472D+00	0.648200D-01	0.651825D-01	-.362475D-03
0.918437D+00	0.989470D-01	0.985864D-01	0.360564D-03
0.890520D+00	0.119982D+00	0.121693D+00	-.171133D-02
0.869068D+00	0.135436D+00	0.136899D+00	-.146329D-02
0.842320D+00	0.151976D+00	0.153309D+00	-.133307D-02
0.823735D+00	0.165190D+00	0.163292D+00	0.189772D-02
0.792527D+00	0.182708D+00	0.177835D+00	0.487340D-02
0.765307D+00	0.193252D+00	0.188534D+00	0.471764D-02
0.738845D+00	0.197315D+00	0.197356D+00	-.408940D-04
0.708304D+00	0.208375D+00	0.205736D+00	0.263893D-02
0.679124D+00	0.211747D+00	0.211989D+00	-.242169D-03
0.655846D+00	0.217483D+00	0.215810D+00	0.167298D-02
0.633601D+00	0.212533D+00	0.218445D+00	-.591246D-02
0.613155D+00	0.219382D+00	0.220002D+00	-.620193D-03
0.587495D+00	0.221691D+00	0.220776D+00	0.915049D-03
0.559544D+00	0.217339D+00	0.220123D+00	-.278402D-02
0.534600D+00	0.217635D+00	0.218235D+00	-.600181D-03
0.529376D+00	0.214724D+00	0.217686D+00	-.296222D-02
0.513456D+00	0.214054D+00	0.215691D+00	-.163723D-02
0.512489D+00	0.211640D+00	0.215555D+00	-.391460D-02
0.493974D+00	0.211692D+00	0.212605D+00	-.912664D-03
0.493567D+00	0.212702D+00	0.212533D+00	0.169214D-03
0.479250D+00	0.205073D+00	0.209817D+00	-.474385D-02
0.467709D+00	0.204068D+00	0.207368D+00	-.330042D-02
0.460552D+00	0.202780D+00	0.205738D+00	-.295775D-02
0.446261D+00	0.203816D+00	0.202234D+00	0.158180D-02
0.442328D+00	0.192670D+00	0.201214D+00	-.854402D-02
0.418731D+00	0.197095D+00	0.194617D+00	0.247846D-02
0.414360D+00	0.191983D+00	0.193315D+00	-.133248D-02
0.392527D+00	0.189177D+00	0.186419D+00	0.275795D-02
0.390818D+00	0.190993D+00	0.185856D+00	0.513721D-02
0.365469D+00	0.179608D+00	0.177140D+00	0.246812D-02
0.364479D+00	0.180706D+00	0.176787D+00	0.391921D-02

x benzene	molar Ve	Ve fit	Error
0.338761D+00	0.172183D+00	0.167331D+00	0.485217D-02
0.319381D+00	0.168569D+00	0.159901D+00	0.866764D-02
0.264791D+00	0.140219D+00	0.138090D+00	0.212928D-02
0.218802D+00	0.120911D+00	0.119222D+00	0.168927D-02
0.181261D+00	0.104382D+00	0.103606D+00	0.775806D-03
0.152473D+00	0.894560D-01	0.913321D-01	-.187611D-02
0.121999D+00	0.798130D-01	0.776992D-01	0.211379D-02
0.795877D-01	0.430330D-01	0.564715D-01	-.134385D-01
0.398951D-01	0.368480D-01	0.321225D-01	0.472549D-02

The standard deviation for this set of fitting constants is: 0.409454D-02

The condition number for the A matrix is: 593.794

APPENDIX D

PROGRAM DOCUMENTATION

```
*   This program is designed to fit the data found in a user specified
*   data file to a smoothing equation which is standard for excess
*   volume data.  The data file must be set up in a specific format,
*   which may be accomplished by using the supplimentary program
*   titled "makefile" to construct the data set.  Actually, the
*   program fits the data for Ve/(x1x2) and then compensates after
*   fitting to arrive at the final Ve-fit data and the correct
*   standard deviation.  This method was chosen to lessen the severity
*   of the ill-conditioning of the matrix while performing the least-
*   squares analysis on the data.  The program utilizes IMSL subroutines
*   to calculate the condition number of the "A" matrix and to solve the
*   linear system of equations.  The user must specify how many fitting
*   constants are desired in the analysis.  (May be between 2 and 5).

*   Variable dictionary:
*        a:  coefficient matrix from |A|x=b
*        b:  solution vector from |A|x=b
*     cond:  the L1 type condition number of matrix A
*    error:  difference between the actual and smoothed excess volume
*      fac:  matrix of the Lu factorization of the A matrix. Not used.
*    gamma:  vector of least-squares fitting constants.
*infofile:  user specified data file containing experimental data
*     ipvt:  vector containing pivoting information.  Not used here.
*        k:  user specified number of fitting constants
*        n:  number of data points in the data file
*    rcond:  inverse of the L1 condition number
*      sse:  sum of the square error for all data points
*        v:  experimental excess volume data
*    vefit:  excess volume from the smoothing equation
*   wkarea:  the work area required by IMSL version 9 routine LEQT2F
*        x:  mole fraction of more volatile component

*   Dimension variables and declare double precision

      real*8 a(5,5),fac(5,5),x(200),v(200),b(5),gamma(5),vefit(200)
      real*8 error(200),wkarea(100),sse,rcond,cond
      integer*4 ipvt(5),k,n
      character*14 infofile

*   Fill data vectors and arrays with zeros

      data a/25*0.0d0/
      data x/200*0.0d0/
      data v/200*0.0d0/
      data b/5*0.0d0/
      data gamma/5*0.0d0/
      data vefit/200*0.0d0/
      data error/200*0.0d0/

*   Interact with user for number of fitting constants and
*   name of data file

      print *, 'How many curve fitting constants do you want?'
      print *, '(must be between 2 and 5)'
      print *
```

```
      read *, k

      print *, 'What is the name of the data file to be used?'
      print *
      print *, '(Data must be stored in x,y pairs with format f7.6,1x,f7.6.'
      print *, ' The first line of the file must contain the number'
      print *, ' of data points in the file, with format I3)'
      print *
      read '(A)',  infofile
      print *
      print *


*     Fill x and V files with experimental data

      open(unit= 1, file= infofile, status= 'old')
      read (1,10),n
10    format(1x,i3)
      read (1,20), (x(i),v(i),i=1,n)
20    format(1x,f7.6,1x,f7.6)
      close(unit= 1)

*     Convert Ve data to form Ve/(x1x2)

      do 50 i=1,n
            v(i)=v(i)/(x(i)-x(i)**2)
50    continue

*     Calculate coefficient matrix

      do 51 j=1,k
            do 52 l=1,k
                  do 53 i=1,n
                        a(j,l)=a(j,l)+(1-2*x(i))**(j+l-2)
53                continue
52          continue
51    continue

*     Calculate solution vector

      do 54 l=1,k
            do 55 i=1,n
                  b(l)=b(l)+v(i)*(1-2*x(i))**(l-1)
                  gamma(l)=b(l)
55          continue
54    continue

*     Call IMSL subroutines...For convenience, both version 9
*     and version 10 function calls are included

      call DLFCRG (K,A,5,FAC,5,IPVT,RCOND)
      call DLSARG (k,a,5,b,1,gamma)
      COND=1.0D0/RCOND
*     (IMSL version 10)
```

```
*       call LEQT2F(a,1,k,5,gamma,4,wkarea,ier)
*       (IMSL version 9)

*  Print least-squares fitting constants

        print 104, (i,gamma(i),i=1,k)
104     format(1x,'gamma ',I1,' =  ',f9.5)
        print *
        print *

*  Calculate Ve fit for each data point and correct to the form
*  Ve from the form Ve/(x1x2).  Also calculate error for each
*  data point and accumulate square error.

        do 204 i=1,n
                do 205 j=1,k
                        vefit(i)=vefit(i)+gamma(j)*(1-2*x(i))**(j-1)
205             continue
                vefit(i)=vefit(i)*(x(i)-x(i)**2)
                v(i)=v(i)*(x(i)-x(i)**2)
                error(i)=v(i)-vefit(i)
                sse=sse+error(i)**2
204     continue

*  Calculate standard deviation for the data set

        sigma=(sse/(n-k))**.5

*  Print data summary point by point

        print *, ' x benzene       molar Ve          Ve fit
     cError'
        print *,'_____________________________________'
        print *
        print 106, (x(i),v(i),vefit(i),error(i),i=1,n)
106     format(1x,4(d12.6,4x))
        print *
        print *
        print *

*  Print standard deviation information

        print 108, sigma
108     format(1x,'The standard deviation for this set of fitting constant
     cs is:  ',d12.6)
        print *
        print *

*  Print the condition number of the A matrix

        PRINT 109, COND
109     FORMAT(1X,'The condition number for the A matrix is: ',f8.3)

        end
```

```
*  This program is designed to supplement the program named curvfit.
*  Its purpose is to create a data file of experimental data points
*  that is in a proper format to be accessed by the curvfit program.
*  This program interacts with the user to determine the name of the
*  data file, and then prompts the user to enter the data in the
*  proper format.  The data are arranged here as a text file, but are
*  read by the program curvfit as numeric.

*  Variable dictionary:
*    infofile :  the user specified name of the data file being made
*           k :  the number of data points to be included in the file
*        line :  the information from a single data point.

*  Declare variables and dimension them

      character *20  line(200), infofile

*  Ask the user for the name of the data file to be created

      print *, 'What is the name of the file you want to create?'
      read '(A)', infofile

*  Read in the data elements to the file, number of data points first.

      open (unit = 1, file = infofile, status = 'new')

      print *, 'How many data points will be in this file?'
      read *, k
      write (1,10), k
10    format(1x,i3)

*  Prompt the user to enter the data points in the correct format.

      print *, 'Enter the data points as x,y pairs, where x is'
      print *, 'the mole fraction of the more volatile component'
      print *, 'and y is the experimental molar excess volume.'
      print *
      print *, '(There should be a space before the x points and'
      print *, ' a space between the x and y points, and their formats'
      print *, ' should be f7.6.)'
      print *
      print *, '    x       Ve'
      print *

*  Read in the data points.

      do 100 i=1,k
            read 20, line(i)
            write (1,20) line(i)
20          format(1x,a20)
100   continue

      close (unit = 1)

      end
```

APPENDIX E

BURET CALIBRATION DATA

APPENDIX E-1

EXPERIMENTAL DATA

TABLE 31

EXPERIMENTAL DATA FOR BURET CALIBRATION

RUN 1

POINT NUMBER	WT OF HG ADDED (G)	HT OF HG IN BURET (CM)	REF LINE HEIGHT (CM)
INITIAL	136.92488	0.2723	0.1575
1	25.31131	2.0117	-0.5710
2	20.76882	3.9717	-0.5063
3	17.22815	5.5975	-0.5184
4	22.66185	7.7166	-0.5101
5	15.37205	9.1562	-0.5276

RUN 2

POINT NUMBER	WT OF HG ADDED (G)	HT OF HG IN BURET (CM)	REF LINE HEIGHT (CM)
INITIAL	147.70806	0.6726	-0.4971
1	14.28067	1.9920	-0.5126
2	14.22029	3.3230	-0.5250
3	12.84957	4.5506	-0.5036
4	13.54833	5.7898	-0.5378
5	13.78516	7.1099	-0.5104
6	13.56552	8.3903	-0.5119
7	17.10570	10.0010	-0.5194

RUN 3

POINT NUMBER	WT OF HG ADDED (G)	HT OF HG IN BURET (CM)	REF LINE HEIGHT (CM)
INITIAL	162.67139	2.0926	-0.4613
1	12.03903	3.1739	-0.5217
2	13.28431	4.4089	-0.5414
3	12.06771	5.5758	-0.5109
4	14.32788	6.8920	-0.5266
5	15.23696	8.3225	-0.5400
6	15.02251	9.7895	-0.4939

APPENDIX E-2

CALCULATED DATA

TABLE 32

CALCULATED DATA FOR BURET CALIBRATION

RUN 1

POINT NUMBER	CHANGE IN HEIGHT (CM)	CROSS SEC. AREA (CM^2)
1	2.4679	0.757827
2	1.8953	0.809687
3	1.6379	0.777203
4	2.1108	0.793289
5	1.4571	0.779517

AVERAGE AREA (CM^2)= .783505

n DEVIATION (CM^2) = .017298

n-1 DEVIATION (CM^2) = .019340

RUN 2

POINT NUMBER	CHANGE IN HEIGHT (CM)	CROSS SEC. AREA (CM^2)
1	1.3349	0.790466
2	1.3434	0.782143
3	1.2062	0.787141
4	1.2734	0.786148
5	1.2927	0.787947
6	1.2819	0.781926
7	1.6182	0.781073

AVERAGE AREA (CM^2) = .785263

n DEVIATION (CM^2) = .003316

n-1 DEVIATION (CM^2) = .003582

VOLUME OF BB (CM^3) = 9.9955

RUN 3

POINT NUMBER	CHANGE IN HEIGHT (CM)	CROSS SEC AREA (CM^2)
1	1.1417	0.779153
2	1.2547	0.782316
3	1.1364	0.784652
4	1.3319	0.794865
5	1.4439	0.779730
6	1.4209	0.781200

AVERAGE AREA (CM^2) = .783653

n DEVIATION (CM^2) = .005325

n-1 DEVIATION (CM^2) = .005833

VOLUME OF BB (CM^3) = 10.0182

APPENDIX F

SAMPLE CALCULATIONS

Sample Calculations

A. Excess volume data.

This set of calculations is taken from dilution run #17, benzene + trichloroethylene 10 ^{o}C, data point 2. Benzene is the solvent.

1. Volume of solvent charged in the mixing bowl:

The following measurements are provided:

Load (Data taken when mixing bowl is full of mercury)

CR	1.6693	cm
C	4.8263	cm
C2	4.7747	cm
C1	4.8066	cm

Initial (Data taken after solvent and solute have been charged)

CR	1.4803	cm
C	3.6977	cm
A	3.1551	cm
C2	0.5530	cm
C1	0.6344	cm
BR	7.41	cm
B	7.53	cm

Cross sectional areas:

C	.01767	cm^2
C1	.01773	cm^2
C2	.01776	cm^2
B	.78452	cm^2

Note: The capillary cross sectional areas were determined in a prior thesis, before the dilatometer was assembled. The buret cross sectional area and the bulb volume were determined in this work. (See buret calibration in the sample calculations).

$$V_{sc} = V_{BB} + B_{ca}(B_i - BR_i) + C1_{ca}[(C1_i - CR_i) - (C1_l - CR_l)] + C2_{ca}[(C2_i - CR_i) - (C2_l - CR_l)] + C_{ca}[(C_i - CR_i) - (C_l - CR_l)]$$

Where: V represents a volume
B refers to buret measurements
BR refers to buret reference line measurements
C1 refers to measurements on capillary C1
C2 refers to measurements on capillary C2
C refers to measurements on capillary C
CR refers to capillary reference line measurements
subscript i indicates an initial measurement
subscript l indicates a load measurement
subscript ca indicates cross sectional area
subscript BB indicates buret bulb
subscript sc indicates solvent charged

For run #17:

$$V_{sc} = 10.0069 + .78452\,(7.53-7.41) + .01773\,[(.6344-1.4803)-(4.8066-1.6693)] + .01776\,[(.5530-1.4803)-(4.7747-1.6693)] + .01767\,[(3.6977-1.4803)-(4.8263-1.6693)]$$

$$= 9.9422 \text{ cc}$$

2. Moles of solvent charged in the mixing bowl:

$$n_{sc} = V_{sc} / v_{solvent}$$

where: n_{sc} is the number of moles of solvent charged
$v_{solvent}$ is the specific volume of the solvent

$$n_{sc} = 9.9422 / 87.8134 = .1132 \text{ gmole}$$

The rest of the data will be illustrated by Figures 17, 18, and 19.

3. Change in height of mercury in buret, B:

$$\text{del } B = (B_2 - BR_2) - (B_1 - BR_1)$$

$$\text{del } B = (8.16 - 7.42) - (7.81 - 7.42) = .35 \text{ cm}$$

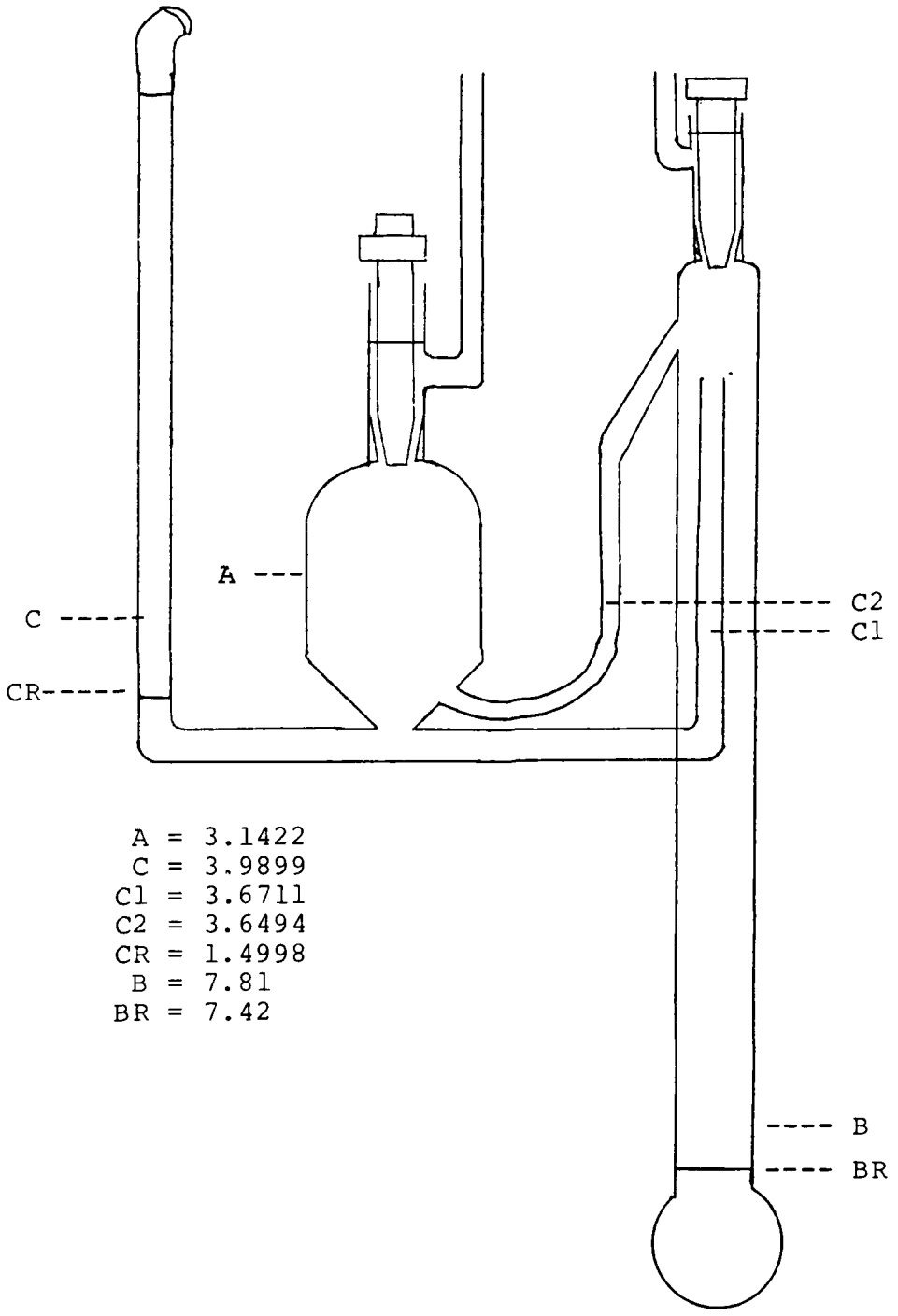
4. Change in height of mercury in capillary C1:

$$\text{del } C1 = (C1_2 - CR_2) - (C1_1 - CR_1)$$

$$\text{del } C1 = (3.6384 - 1.4938) - (3.6711 - 1.4998) = -.0267 \text{ cm}$$

FIGURE 17

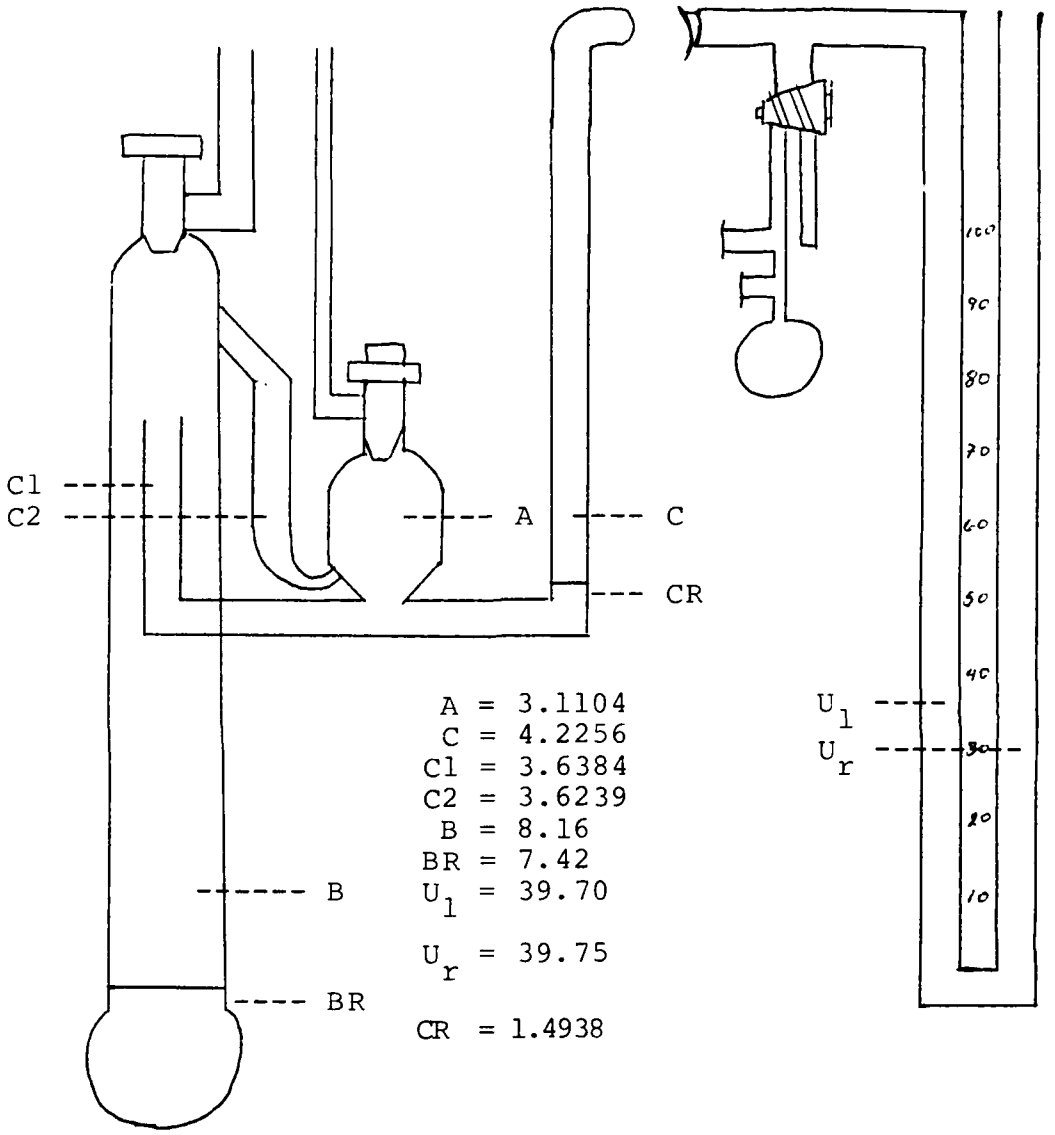
RUN #17, DATA POINT #1



A = 3.1422
C = 3.9899
C1 = 3.6711
C2 = 3.6494
CR = 1.4998
B = 7.81
BR = 7.42

FIGURE 18

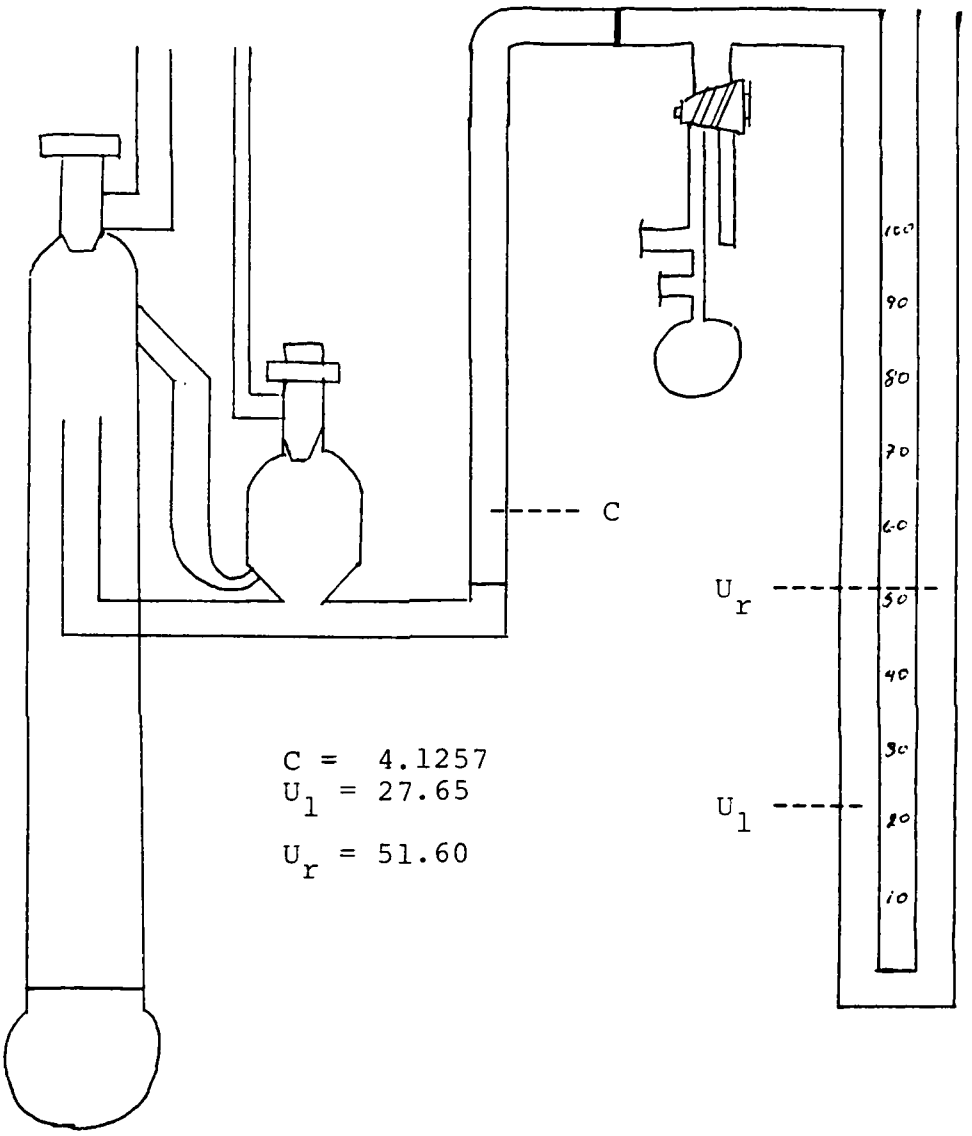
RUN #17, DATA POINT #2 BEFORE PRESSURE CORRECTION



A = 3.1104
C = 4.2256
C1 = 3.6384
C2 = 3.6239
B = 8.16
BR = 7.42
U_l = 39.70
U_r = 39.75
CR = 1.4938

FIGURE 19

RUN #17, DATA POINT #2 AFTER PRESSURE CORRECTION



C = 4.1257
U_l = 27.65
U_r = 51.60

5. Change in height of mercury in capillary C2:

$$\text{del } C2 = (C2_2 - CR_2) - (C2_1 - CR_1)$$

$$\text{del } C2 = (3.6239 - 1.4938) - (3.6494 - 1.4998)$$

$$= -.0195 \text{ cm}$$

6. Change in height of mercury in capillary C:

$$\text{del } C = (C_{B2} - CR_2) - (C_{B1} - CR_1)$$

$$\text{del } C = (4.2256 - 1.4938) - (3.9899 - 1.4998)$$

$$= .2417 \text{ cm}$$

7. Change of height of mercury in mixing bowl:

$$\text{del } A = (A_2 - CR_2) - (A_1 - CR_1)$$

$$\text{del } A = (3.1104 - 1.4938) - (3.1422 - 1.4998)$$

$$= -.0258 \text{ cm}$$

8. Volume of solute added to solvent:

$$\text{del } V_c = (\text{del } B)*B_{ca} + (\text{del } C1)*C1_{ca} + (\text{del } C2)*C2_{ca}$$

$$\text{del } V_c = (.35)*.78452 + (-.0267)*.01773$$

$$+ (-.0195)*.01776 = .27376 \text{ cc}$$

9. Number of moles of solute added to the solvent:

$$\text{del } n_c = \text{del } V_c / v_{solute}$$

$$\text{del } n_c = .27376 / 88.627319 = .003089 \text{ gmole}$$

10. Total number of moles of solute in the mixing bowl:

$$n_cTOT_2 = n_cTOT_1 + \text{del } n_c$$

$$n_cTOT_2 = .003610 + .003089 = .006699 \text{ gmole}$$

11. Mole fraction of benzene in mixing bowl:

$$x \text{ (Benz)} = n_{sc} / (n_{sc} + n_cTOT)$$

$$x(\text{Benz}) = .1132 / (.1132 + .006699) = .9441$$

12. Cumulative height change of mercury in capillary C:

$$CTOT_2 = CTOT_1 + \text{del } C$$

$$CTOT_2 = .27268 + .2417 = .5144 \text{ cm}$$

13. Pressure corrected change in height of mercury in capillary C:

$$\text{del C pi} = C_{A2} - C_{B2}$$

$$\text{del C pi} = 4.1257 - 4.2256 = -.0999 \text{ cm}$$

14. Back-pressure applied:

$$\text{del U} = (U_{lb} - U_{rb}) + (U_{ra} - U_{la})$$

$$\text{del U} = (39.70 - 39.75) + (51.60 - 27.65) = 23.90 \text{ cm}$$

15. Excess volume (pressure corrected): (Kumaran, p. 265)

$$V^E = \text{CTOT} * C_{ca} * [1 - (\text{del C pi} / \text{del U})] * [1 - (\text{del A} / \text{CTOT})]$$

$$V^E = .5144 * .01767 * [1 - (-.0999/23.90)] * [1 - (-.0258/.5144)]$$

$$V^E = .009585 \text{ cc}$$

16. Molar excess volume (pressure corrected):

$$V_{em} = V^E / (n_{sc} + n_c\text{TOT})$$

$$V_{em} = .009585 / (.1132 + .006699) = .0799 \text{ cc/gmole}$$

B. Buret Calibration Data

Calibration was conducted at 24.947 ^{o}C. The mercury density at this temperature is 13.5337 g/cc. This value was obtained from Figure 20.

1. Cross sectional area (using run #2 point 1):

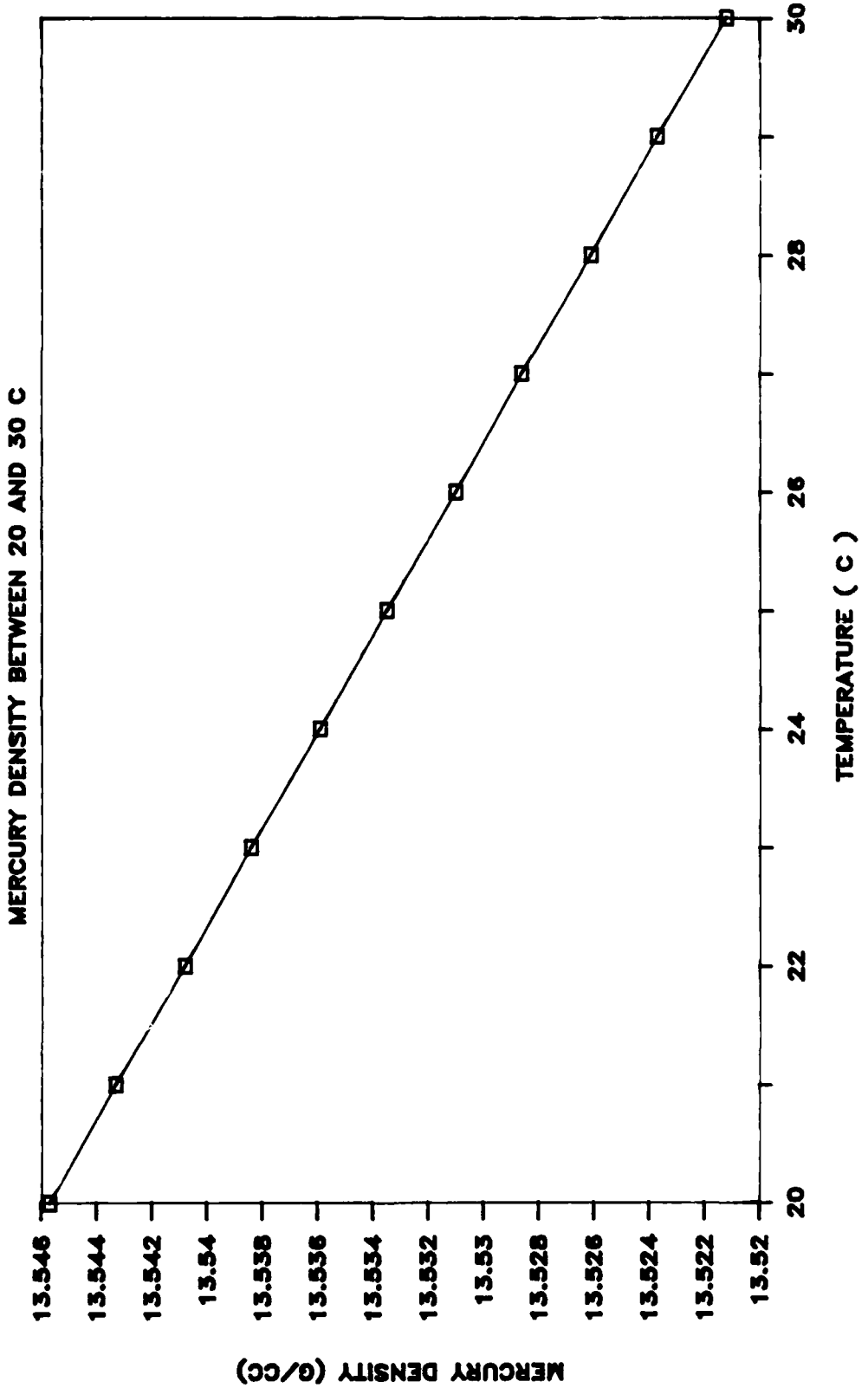
$$A = w / (\rho * \Delta h)$$

where: A is the cross sectional area
w is the weight of mercury added
ρ is the density of mercury
Δh is the change in height of mercury

$$\Delta h = (2.5046 - 1.1697) = 1.3349 \text{ cm}$$

$$A = 14.28067 / (13.5337 * 1.3349) = .7904662 \text{ cm}^2$$

FIGURE 20


MERCURY DENSITY BETWEEN 20 AND 30 C
MERCURY DENSITY (g/cc)
13.546
13.544
13.542
13.54
13.538
13.536
13.534
13.532
13.53
13.528
13.526
13.524
13.522
13.52
TEMPERATURE (C)
20
22
24
26
28
30

2. Average cross sectional area and standard deviations (using run #2):

$$\bar{A} = \sum A_i / n$$

where: $\bar{A}$ is the average cross sectional area
A_i is the cross sectional area of data point i
n is the number of data points in the run

Using the statistical functions on a Texas Instruments TI-55 III calculator,

$\bar{A} = 5.4968473 / 7 = .7852639 \text{ cm}^2$

$\sigma_n = .0033168$

$\sigma_{n-1} = .0035825$

Note: The final A value used was that calculated from the 13 data points in runs 2 and 3 combined. Run 1 was discarded due to poor agreement with the other runs.

3. Volume of the bulb BB (from run #2):

V_{BB} = Volume of mercury initially charged - volume of mercury above BR

Weight of mercury charged = 147.70806 g
Height of mercury charged = 1.1697 cm above BR
A = .7853 cm_2

Weight of mercury above BR: $w = A * \rho * \Delta h$

$w = .7853 * 13.5337 * 1.1697 = 12.431589$ g

Weight of mercury below BR = weight of mercury charged - weight of mercury above BR

Weight of mercury below BR = 147.70806 - 12.431589

= 135.27647 g

V_{BB} = weight of mercury below BR / density if mercury

$V_{BB} = 135.27647 / 13.5337 = 9.9955$ cc

Note: The volume used for the bulb was the average for runs 2 and 3.

APPENDIX G

NOMENCLATURE

NOMENCLATURE

A	Mixing bowl on the dilatometer
$\overline{A}$	Average cross sectional area
A_i	Cross sectional area of data point i
a_j	Least-squares fitting constants
B	Buret on the dilatometer
BB	Bulb at the bottom of buret
B_{ca}	Buret cross sectional area
BR	Reference mark on the buret
C	Condition number
C, C1, C2	Capillary tubes on the dilatometer
$C, C1, C2_{ca}$	Capillary cross sectional area
CR	Reference mark on capillary C
CTOT	Cumulative change in height of mercury in C
del A	Change in height of mercury in mixing bowl
del B	Change in height of mercury in buret
del C,C1,C2	Change in height of mercury in a capillary
del C pi	Pressure corrected change in height of mercury in C
del n_c	Number of moles of solute added to solvent
del V_c	Volume of solute added to the solvent
del U	Back-pressure applied to C
G^E	Excess Gibbs free energy of mixing
m	Number of data points used to fit a curve
n	Number of coefficients in least-squares fit

n	Number of data points in buret calibration run
$n_c TOT$	Total number of moles of solute in mixing bowl
n_{sc}	Number of moles of solvent charged
P	Total pressure
S1, S2	Vent tubes on the dilatometer
T	Temperature
T1, T2	Taps on the dilatometer
U_i	Back-pressure reading i on U tube
V_{BB}	Volume of bulb BB
V^E	Excess molar volume of mixing
V_{eT}	Maximum excess volume at temperature T
$\overline{V}_i$	Partial molar volume of component i
V_i^o	Molar volume of component i in solution
V^{ID}	Molar volume of an ideal solution
V_i^E	Excess volume of mixing for data point i
V_{sc}	Volume of solvent charged
v_{solute}	Specific volume of the solute
$v_{solvent}$	Specific volume of the solvent
w	weight of mercury added
x (Benz)	Mole fraction of benzene in mixing bowl
x_i	Mole fraction of component i in solution
Δh	Change in height of mercury in calibration run
ΔV	Molar volume change on mixing
σ_n	Population standard deviation
σ_{n-1}	Standard deviation of a point
ρ	Density

BIBLIOGRAPHY

Beath, L.A.; O'Neill, S.P.; Willaimson, A.G., "Thermodynamics of Ether Solutions II. Volumes of Mixing of Ethers with Carbon Tetrachloride and with Chloroform at 25 C", J. Chem. Thermodynamics, Vol. 1 (1969), pp. 293-300.

Bottomly, G.A. and Scott, R.L., "A Grease-free Continuous Dilution Dilatometer; Excess Volumes for Benzene + Carbon Tetrachloride", J. Chem. Thermodynamics, Vol. 6 (1974), pp. 973-981.

Dickinson, Eric; Hunt, David C.; McLure, Ian A., "Excess Volumes of Mixing of Nearly Spherical Molecules 2. Mixtures ContainingCyclic Dimethylsiloxanes", J. Chem. Thermodynamics, Vol. 7 (1975), pp. 731-740.

Duncan, W.A.; Sheridan, J.P.; Swinton, F.L., "Thermodynamic Properties of Binary Systems Containing Hexafluorobenzene Part 2.- Excess Volumes of Mixing and Dipole Moments", Trans. Faraday Soc., Vol. 62 (1966), pp. 1090-1096.

Gallant, R.W., Physical Properties of Hydrocarbons, Gulf Publishing Co., Houston, 1968.

Goates, J. Rex; Ott, J. Bevan; Grigg, Reid B., "Excess Volumes of Cyclohexane + n-Hexane, + n-Heptane, + n-Octane, + n-Nonane, and + n-Decane", J. Chem. Thermodynamics, Vol. 11 (1979), pp. 497-506.

Goates, J.R.; Ott, J.B.; Moellmer, J.F., "Determination of Excess Volumes in Cyclohexane + Benzene and + n-Hexane with a Vibrating-tube Densimeter", J. Chem. Thermodynamics, Vol. 9 (1977), pp. 249-257.

Handa, Yash Paul and Benson, George C., "Volume Changes on Mixing Two Liquids: A Review of the Experimental Techniques and the Literature Data", Fluid Phase Equilibria, Vol. 3 (1979), pp. 185-249.

Kumaran, M.K. and McGlashan, M.L., "An Improved Dilution Dilatometer for Measurements of Excess Volumes", J. Chem. Thermodynamics, Vol. 9 (1977), pp. 259-267.

Maron, M.J., Numerical Analysis: A Practical Approach, 2nd ed., Macmillan, New York, 1987.

Marsh, K.N.; McGlashan, M.L.; Warr, Christina, "Thermodynamic Excess Functions of Mixtures of Simple Molecules According to Several Equations of State:, Trans. Faraday Soc., Vol. 66 (1970), pp. 2453-2458.

Picker, Patrick; Tremblay, Edmond; Jolicoeur, Carmel, "A High-Precision Digital Readout Flow Densimeter for Liquids", J. Solution Chemistry, Vol. 3, No. 5 (1974), pp. 377-384.

Prausnitz, J.M.; Lichtenthaler, R.N.; de Azevedo, E.G., Molecular Thermodynamics of Fluid-Phase Equilibria, 2nd ed., Prentice-Hall, Englewood Cliffs, New Jersey, 1986.

Powell, R.J. and Swinton, F.L., "Excess Volumes of Mixing: Benzene - Cyclohexane and Benzene - Diphenylmethane Systems", J. Chem. and Eng. Data, Vol. 13, No. 2 (1968), pp. 260-262.

Smith, J.M. and Van Ness, H.C., Introduction to Chemical Engineering Thermodynamics, 3rd ed., McGraw-Hill, New York, 1970.

Stokes, R.H.; Levien, Barbara A.; Marsh, K.N., "A Continuous Dilution Dilatometer: The Excess Volume for the System Cyclohexane + Benzene", J. Chem. Thermodynamics, Vol. 2 (1970), pp. 43-52.

Stookey, D.J.; Sallak, H.M.; Smith, B.D., "Excess Volumes of some Aromatic + Cycloparaffin Mixtures. Analysis of Experimental Errors in Dilatometers using V-shaped Cells", J. Chem. Thermodynamics, Vol. 5 (1973), pp. 741-751.

Tanaka, R. et al., "A Micrometer Syringe Dilatometer: Application to the Measurement of the Excess Volumes of some Ethylbenzene Systems at 298.15 K", Can. J. Chem., Vol. 53 (1975), pp. 2262-2267.

Thermodynamics Research Center, API Research Project 44, Texas A & M University, College Station, TX, 1977.

Weeks, I.A. and Benson, G.C., "Determination of the Excess Volume of Cyclohexane + Benzene by Means of a Magnetic Float Densimeter", J. Chem. Thermodynamics, Vol. 5 (1973), pp. 107-115.

Wilhelm, Emmerich; Grolier, J.P.E.; Ghassemi, M.H. Karbalai, "Determination of Excess Volumes in 1,2-Dichloroethane + Benzene, + Toluene, + p-Xylene, + Cyclohexane, and + Methylcyclohexane with a Vibrating-Tube Densimeter", Monatshefte für Chemie, Vol. 109 (1978), pp. 369-374.

VITA

The author, Captain David Steven Pickerell, [redacted] of Richard Duane Pickerell and G. Lynn ([redacted] Pickerell.

[redacted]

His elementary education was obtained in the public schools of Fairborn, Ohio, and secondary education at Park Hills High School, Fairborn, Ohio, where he graduated in 1974, ranking seventh in his class.

In July, 1974, he entered the United States Military Academy at West Point, New York. In 1978, he graduated with a Bachelor of Science degree, concentrating in chemistry. Upon graduation, he was commissioned as a second lieutenant in the United States Army.

He has served as an Armored Cavalry Platoon Leader, Logistics Officer for an Armored Cavalry Squadron, and Commander of a Cavalry Troop. In December of 1983, he was married to Jeannette Rae Harvie. He currently has two children, Anna Christine, and Rebekah Kay, and is expecting a third in December. His hobbies include gardening, skiing, and other forms of athletic endeavor.